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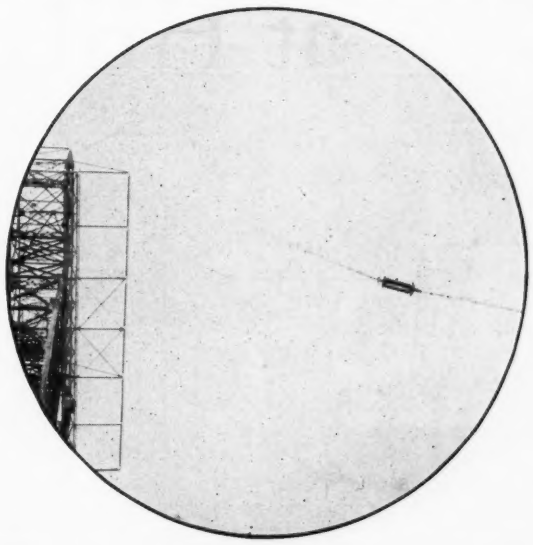


How Anaximander Discovered the Nesonoboid

"QUICK, ANAXIMANDER, train your telescope on that strange creature hovering about the transmission tower. How it writhes and squirms! I fear disaster will come to the power supply line to yon great city."

"Calm yourself, Demetrius, this powerful glass has never failed to envisage the minutest of animals,—besides the power system is well protected with auxiliary lines. My word, what a strange object! A sea serpent in air. I declare, the thing has fins on its back and belly and a stripe along the side. No,—that's not a stripe, the thing is double bodied, connected at both ends—double Siamese twins, what? But a serpent, I swear, for it has a sword at each end to fight with, both approaching and retreating. It weaves its body like an alligator, but look, it goes up and down and around in a circle just getting set for a dive at that tower. There, see it jerk. Ye Gods, what dangers await us with flying double-ended swordfish so bold as to attack transmission towers! Ah! Now I have it, Demetrius. That is the nesonoboid, a recently evoluted entheumasis which has the power to resist the passage of electricity even at pressures of hundreds of thousands of volts."

This strange discovery aroused the photographer's instinct in Mr. Fowler and as a result we have the picture at the head of this column of a nesonoboid, if you wish to dignify a high-tension insulator by giving it a Greek name, being installed on one of the towers that support 2000-ft. spans from Edgar Station. How Mr. Fowler uses photographs in making aerial surveys is described on page 636 of this issue.

Features of new

320,000-kw. Extension at HELL GATE

Hell Gate Station was first placed on the line in November, 1921, with a capacity of 75,000 kw. in two turbine units, one of 35,000 kw. and the other of 40,000 kw. capacity. These were large units 9 yr. ago. Last year, two other units were installed at Hell Gate, the combined capacity of which is 320,000 kw. Some measure of the progress made in power plant engineering is had in the comparison of these last two units with the first 35,000-kw. machine.

FEW OF THE major power stations in this country have expanded as rapidly as the Hell Gate Station of the United Electric Light and Power Co. Since ground was first broken for the initial unit on March 9, 1920, the history of Hell Gate station has been characterized by almost continual expansion. Opening in November, 1921, with a capacity of 75,000 kw., followed two months later with the addition of two other units totaling 75,000 kw., the total capacity installed February, 1922, was 150,000 kw. In 1923 a 35,000-kw. generating unit was added, followed by a 50,000-kw. unit in 1924 and still another 50,000-kw. unit in 1925. This gave the station a total capacity in 1926 of 285,000 kw.

When Hell Gate was first designed, an ultimate capacity of 300,000 kw. was planned for. With the size and types of turbines then available, this was believed to be as much capacity as could possibly be installed in the available ground area. As the station grew, however, and with the production of larger turbine generators, it was evident that considerably more capacity than an additional 50,000-kw. unit as called for could be installed, with the consequence that when the 1928 extension was contemplated, it was decided to install two 160,000-kw. turbines or a total of some 320,000 kw. additional.

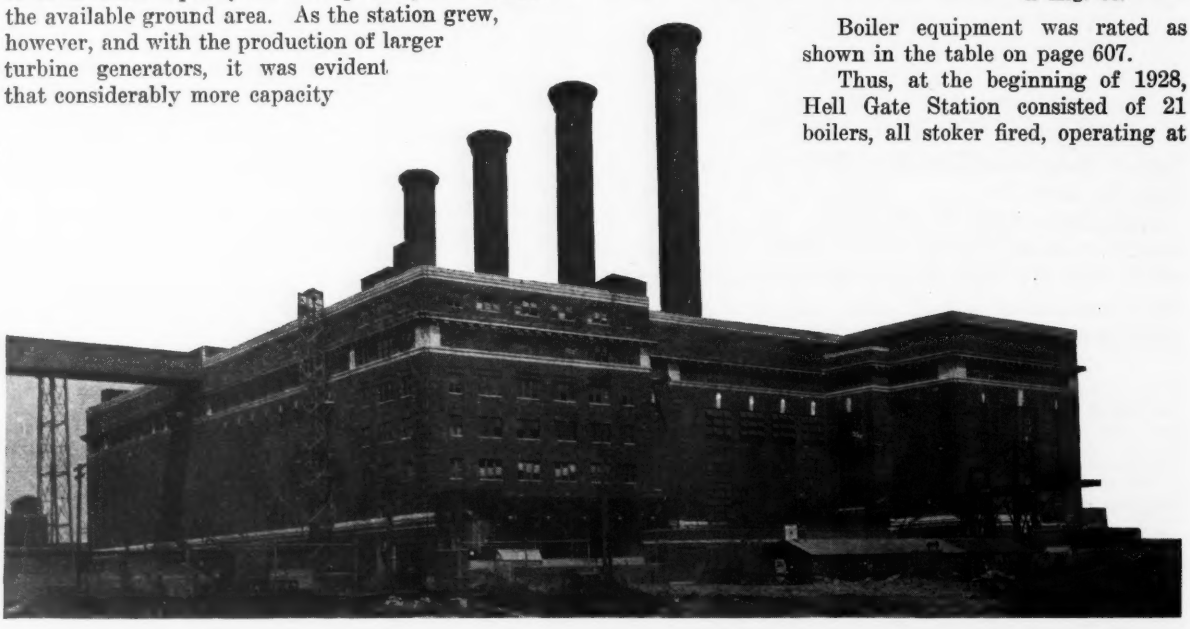
Before presenting a detailed description of the engineering features of the 1928 extension, however, it may be of interest to describe briefly the type of equipment installed in the station just previous to the work done in 1928.

As may be noted from Fig. 3, at that time the equipment consisted of 21 boilers, arranged in 7 rows of 3 boilers each, and 7 turbine generator units of varying types and capacities. The latter were designated as follows:

No. of unit	Size in kw.	Voltage and frequency	Make
2, 3 and 5....	35,000 kw.	11,400 v., 25 cycles	General Elec. Co.
1 and 4.....	40,000 kw.	13,200 v., 60 cycles	Westinghouse Elec. & Mfg. Co.
6 and 7.....	50,000 kw.	13,200 v., 60 cycles	Westinghouse Elec. & Mfg. Co.

Boiler equipment was rated as shown in the table on page 607.

Thus, at the beginning of 1928, Hell Gate Station consisted of 21 boilers, all stoker fired, operating at



275 lb. steam pressure, and 7 turbo-generators, totaling 285,000 kw. capacity.

The 1928 extension consisted of two 160,000-kw. turbine generators (Nos. 8 and 9) and 3 new boilers (Nos. 81, 82, 83).

There was sufficient space in the turbine room for the installation of one 160,000-kw. machine but not for two such units. It was necessary, therefore, first to enlarge the turbine room. This consisted in building a 70-ft. extension to the north end of the turbine room.

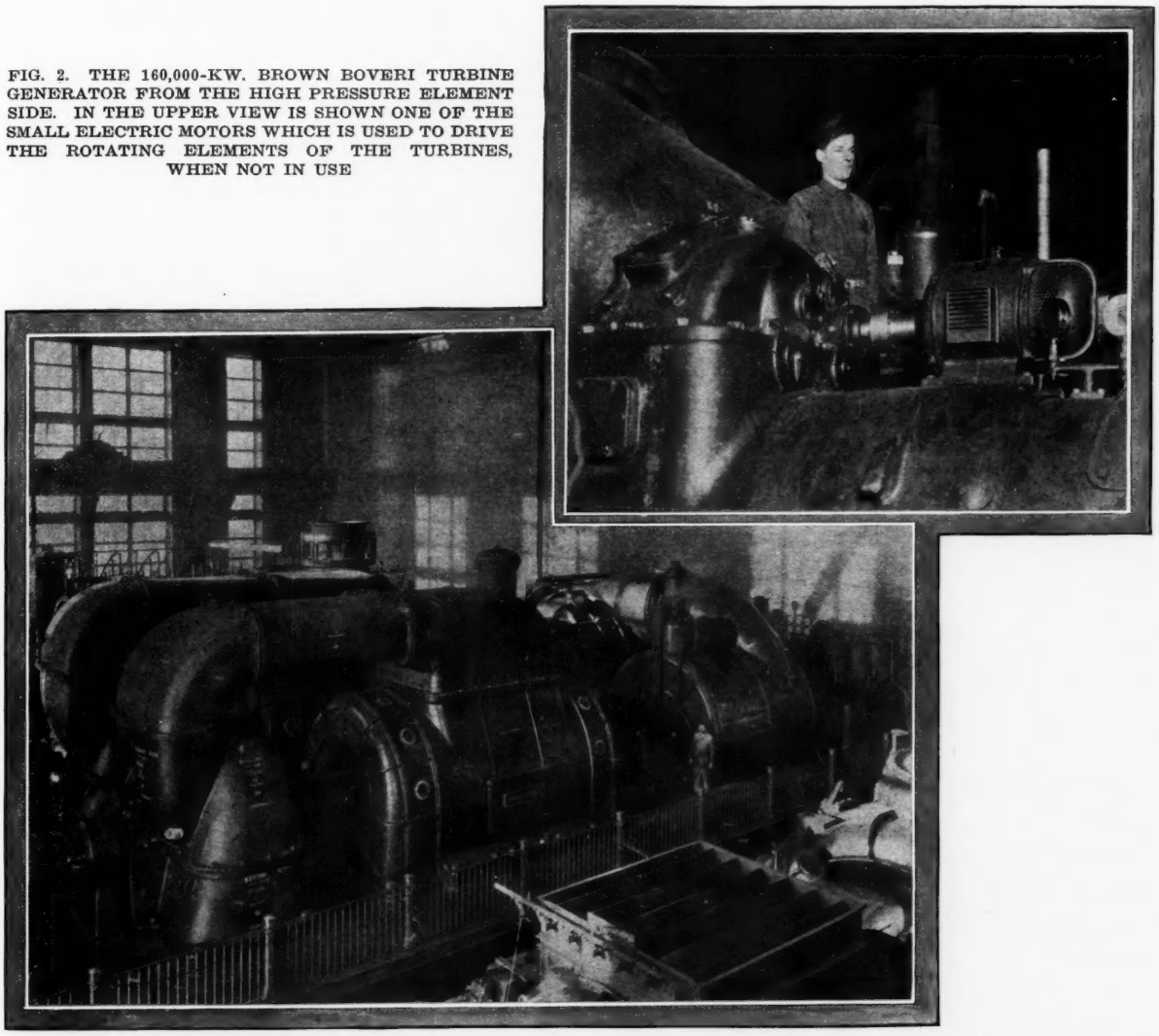


FIG. 2. THE 160,000-KW. BROWN BOVERI TURBINE GENERATOR FROM THE HIGH PRESSURE ELEMENT SIDE. IN THE UPPER VIEW IS SHOWN ONE OF THE SMALL ELECTRIC MOTORS WHICH IS USED TO DRIVE THE ROTATING ELEMENTS OF THE TURBINES, WHEN NOT IN USE

The boiler room was not enlarged, since there was space in the existing building for the installation of three new boilers. Due to the increased need for steam by the two new turbines, however, still more boiler capacity is needed, and during the next year the boiler house will also be enlarged so as to accommodate two additional boilers of 800,000 lb. capacity each.

This addition gives Hell Gate station a capacity of 605,000 kw., making it the world's largest central station plant in service today.

Details of New Boiler Installation

Of considerable interest is the fact that the three new boilers (Nos. 81, 82 and 83) included in the 1928 extension are fired with pulverized coal, these units being the first pulverized coal fired units to be installed at Hell Gate. Like all the other boilers in this station the new units are three-pass, cross-drum Springfield boilers. They are built to operate at 275 lb. pressure and are connected into the same header system as the old boilers.

While the use of pulverized coal is new at Hell Gate, it is by no means an experiment. For several years, this company has had pulverized coal-fired boilers in operation at the Sherman Creek station where considerable experimental work was carried out. It was be-

BOILERS AT HELL GATE AT BEGINNING OF 1928

	Orig. Installation	Gen. Unit No. 5	Gen. Unit No. 6	Gen. Unit No. 7
Number of units	12	3	3	3
Make of boiler..	Springfield	Springfield	Springfield	Springfield
Type.....	Cross Drum	Sectional	Water Tube	Water Tube
Boiler pressure.	275	275	275	275
Capacity.....	1890	1590	1256	1256
Method of firing	Taylor stokers	Taylor stokers	Taylor stokers	Taylor stokers

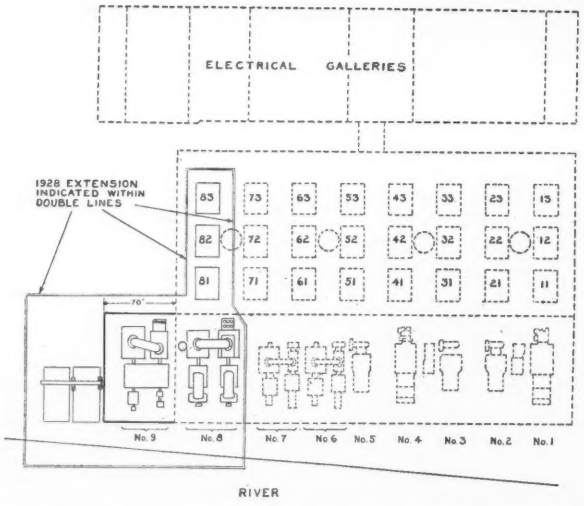


FIG. 3. PLAN OF HELL GATE STATION SHOWING EQUIPMENT INCLUDED IN THE 1928 EXTENSION AND ITS RELATION TO PREVIOUSLY INSTALLED UNITS

cause of this experimental work at Sherman Creek that pulverized coal was decided upon for the new Hell Gate units.

A section through one of the new boilers is shown in Fig. 4. As may be noted, it has three drums. One of the outside drums is connected directly with the boiler heating surface proper. Each of the three drums, however, connects with the water walls of the furnace. The furnaces are entirely water cooled by means of fin tube type walls furnished by the Combustion Engineering Corp. The furnace on boiler No. 81 has water screens at the bottom, but not unit No. 82 and 83.

Of particular interest in connection with the water walls is the method of protecting the headers from the action of the intense heat of the furnace. These are insulated with R & E moldit, a monolithic refractory which is prepared by merely adding water and poured into place. Wooden forms are built around these headers, and the refractory poured in place much as cement is poured into forms in ordinary cement construction. This refractory, shown in Fig. 5, which was installed by the Refractory and Engineering Corp., not only protects the header but effectively seals the furnace at this point against air leakage, as it has no drying shrinkage. It has another advantage. If during continued operation, this refractory around the upper headers should tend to loosen and fall, it will crumble gradually, thus eliminating the possibility of damage to the water screen below due to the impact of large blocks of refractory.

Each of the new boilers is rated at 2380 hp., having 20,000 sq. ft. of water heating surface in the boiler proper and 3800 sq. ft. in the water walls. The furnace volumes of the various units differ slightly, owing to the different arrangements used for removing the ash, unit No. 81 having 18,300 cu. ft.; No. 82, 21,840 cu. ft., and No. 83, 18,150 cu. ft.

The superheaters are of the bent tube type made by the Superheater Co. and have 4800 sq. ft. of heating surface. They are installed in the first pass of the boiler, between the lower and upper banks of boiler tubes. The lower bank of tubes contains 4 rows, the upper bank 16.

As may be noted from Fig. 4, the superheater is composed of two sets of elements, an upper set and a lower set, each set, however, connecting into the same headers. The latter pass directly through the center of the boiler and are isolated from the gas passage by a refractory casing.

The boilers are suspended by U-shaped rods from girders above the drums, and are provided with a plaster setting. Water-cooled furnace walls are insulated with 1⅞ in., 1800 semi refractory, 4 in. Webers' No. 48 plaster, finished with ⅛ in. hard cement.

Method of Firing

In firing these units, the tangential system of firing is used, the furnaces being provided with a 3-element burner at each of the four corners. The Combustion Engineering Corp. unit system of preparation is used with mill drying. The mills are Raymond, impact No. 82, with a capacity of 12,500 lb. per hr., one being provided for each burner or four for each boiler.

Crushed coal is delivered to the 100-t. raw coal

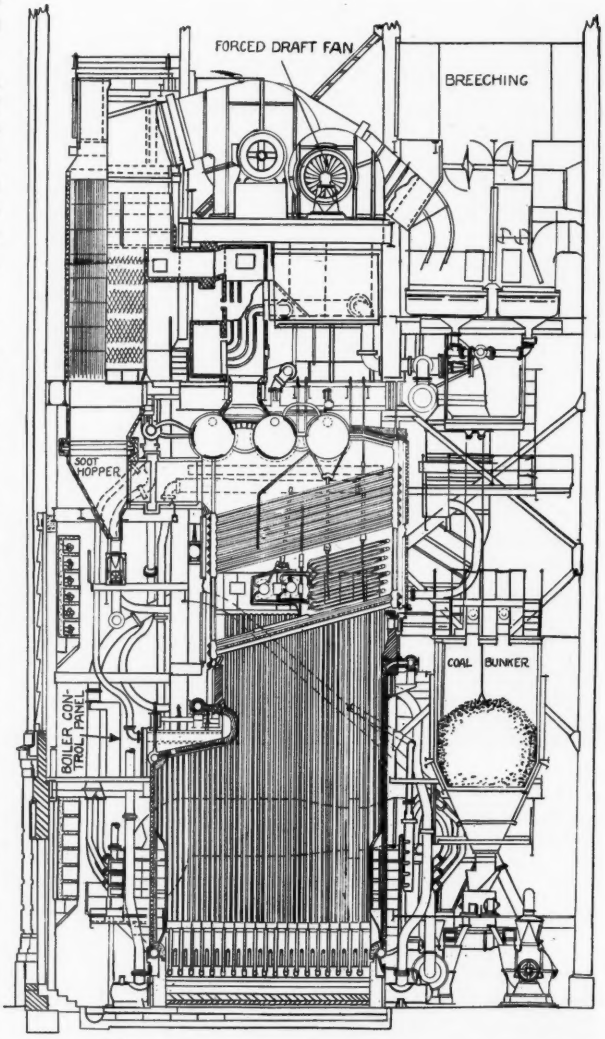


FIG. 4. CROSS SECTION OF ONE OF THE NEW BOILERS AT HELL GATE STATION

bunkers at each boiler by either of two screw conveyors as shown. From the bunkers, the coal feeds directly into the four motor-driven feeders which in turn deliver it, by gravity, to the respective mills, where it is pulverized.

At the mills, approximately 15 per cent of the total air required for combustion is supplied. This air is supplied from the air preheaters at a temperature of 280 deg. F.

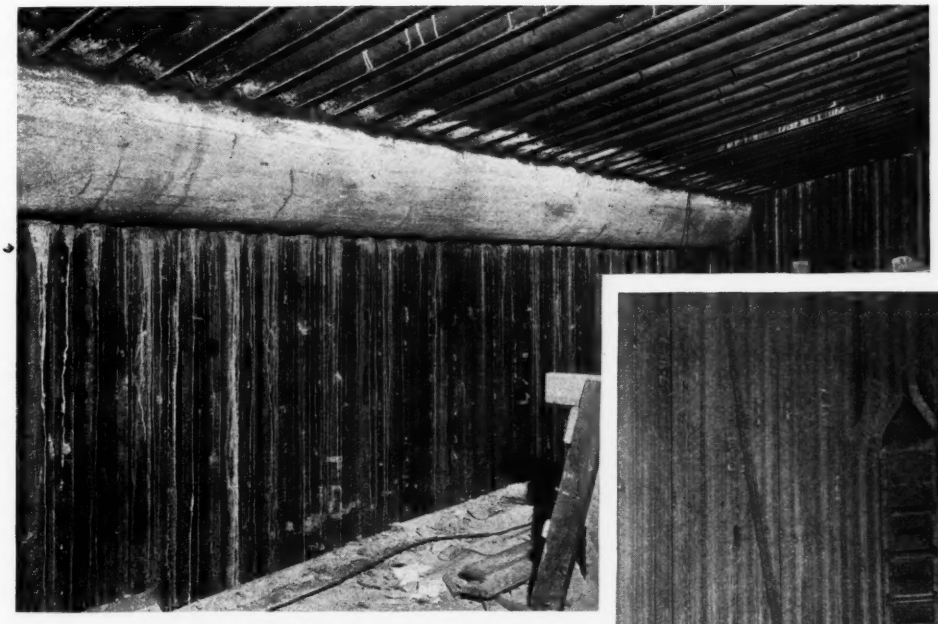


FIG. 5. A VIEW INSIDE THE FURNACE AT HELL GATE, SHOWING THE WATER WALLS AND PART OF THE WATER COOLED ARCH. THIS ALSO SHOWS HOW THE WATER WALL HEADER IS PROTECTED BY THE MONOLITHIC REFRACTORY

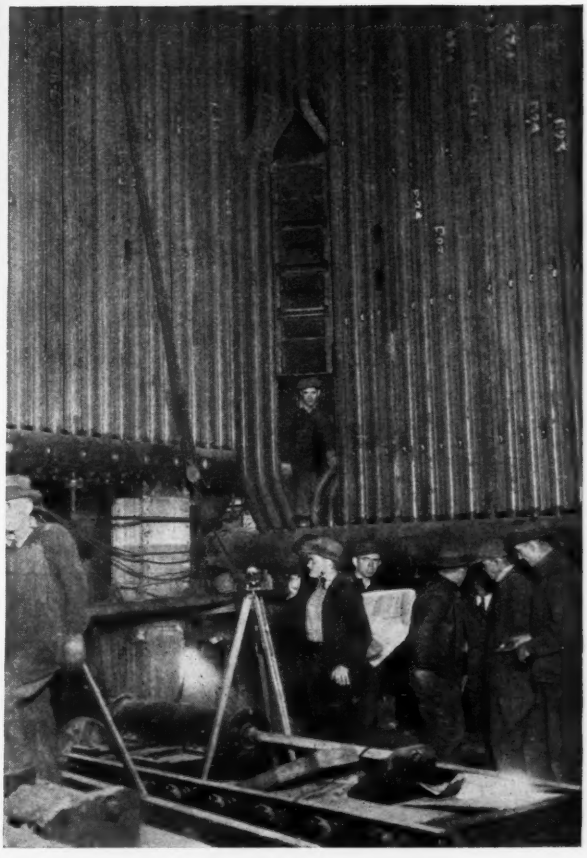


FIG. 6. ANOTHER VIEW INSIDE THE FURNACE, LOOKING AT A CORNER AND SHOWING ONE OF THE TANGENTIAL BURNERS

A separate feed pipe is installed from each mill to one of the burners. At a point close to the burners, this single line divides into three smaller lines which deliver the pulverized coal to each of the three elements of the burner. At the burners, the remainder of the air required for combustion, i. e., about 85 per cent, is supplied, also at a temperature of 280 deg. F. Thus, all the air is admitted into the furnace directly at the burners; none enters the furnace at any other point, except such as may enter through leakage.

The burners are so directed, that the four streams of flame are tangent to a 6-ft. circle at the center of the furnace. As may be seen, the burners are installed in the lower part of the furnace. Due to the tangential arrangement of the burners, a violent turbulence is set up at the center of the furnace and, as the coal is thus brought into intimate contact with the air and as combustion is effected, the hot gases are drawn upward into the boiler. By locating the burners close to the bottom of the furnace and by inducing sufficient turbulence, combustion is practically complete by the time the lower tubes of the boiler are reached.

An extremely interesting feature of the design of the new boiler installation at Hell Gate is the arrangement of the air preheaters and economizers. Instead of the usual arrangement of placing these in series with respect to the gas passage, at Hell Gate they are placed in parallel. If Fig. 4 is examined rather carefully, it may be seen that there are two gas outlets to the boiler, one directly below the first drum, leading directly to the economizer, and another at the top of the boiler, between the first and second drums, leading directly to the air preheater. The gases leaving through the latter opening pass through the air preheater and finally meet the gases leaving the economizer, from which meeting point both are drawn into the induced draft fans, after which they are delivered through cinder catchers to the uptake. Thus it is seen that the gases leaving the boiler divide into two parts, one part going through the economizers while the remainder passes through the air heaters.

It will be noted that in the gas passage leading from the air preheater, there is installed a damper. The purpose of this is to regulate the amount of gas passing through the air heater and therefore, the air tempera-

ture. By adjusting this damper, any desired air temperature can be obtained. When the damper is closed, the air preheaters are out of the circuit entirely and the entire quantity of gases leaving the boiler passes through the economizers.

The economizers are of two makes, those on units 81 and 82 being Foster Wheeler Corp. units and that on No. 83, a Combustion Engineering unit. The Foster Wheeler units each have 26,136 sq. ft. of heating surface while the Combustion Engineering Corp. unit has 27,836 sq. ft.

Air preheaters on all three boilers are the C. E. plate type, having 11,840 sq. ft. of surface and a capacity of 456,700 lb. of air per hour. They are designed for raising the temperature of the air from 70 to 286 deg. with gas inlet and outlet temperatures of 820 and 484 deg. respectively.

One forced draft fan and one induced draft fan are provided for each boiler, both being installed above the boilers as shown. Both fans are Sturtevant units, the induced draft fan being of the new adjustable vane type, capable of handling 275,000 c.f. at 14 in. S.P. The forced draft fans have rating of 155,000 c.f. at 10 in. static pressure.

Method of Control

Entire control of each boiler is effected by the automatic control system or manually by means of a boiler control panel on the operating floor in front of each boiler. Each boiler panel contains, beside the Bailey boiler meter, draft gages showing the induced draft pressure, the draft pressure at the boiler outlet and the draft pressure at each of the four burners, a steam pressure gage, an indicating pyrometer and the manual controls for the various fan and mill motors.

The controls on the panel only regulate the speeds of the various motors. To adjust the air supply to the burners, a separate set of controls is provided. This consists of six hand wheels operating the dampers at the burners, through steel cables installed on pulleys.

Each of the four upper and lower elements of the burners for one furnace is controlled by a single hand wheel respectively. The center elements of each of the four burners are each controlled by a separate control wheel. Thus there is one control for all of the upper elements, one for all of the lower elements, and four controls, one each for each of the center elements of the four burners.

As stated previously, only boiler 81 has a water screen. Because of the great height of the furnaces, it was necessary to install the water screens only a few feet above the basement floor level, thus making it impossible to install the usual type of ash pit below. The ash, therefore, is removed at the sides, the bottom of the furnace being inclined at each side. These inclined bottoms are provided with Allen-Sherman-Hoff hydraulic ash gates as shown in Fig. 9C.

All ash disposal is by the hydraulic sluicing system used throughout the entire station. Ash from the boiler furnaces is discharged into cast-iron lined troughs immediately below the furnaces. These troughs, one for

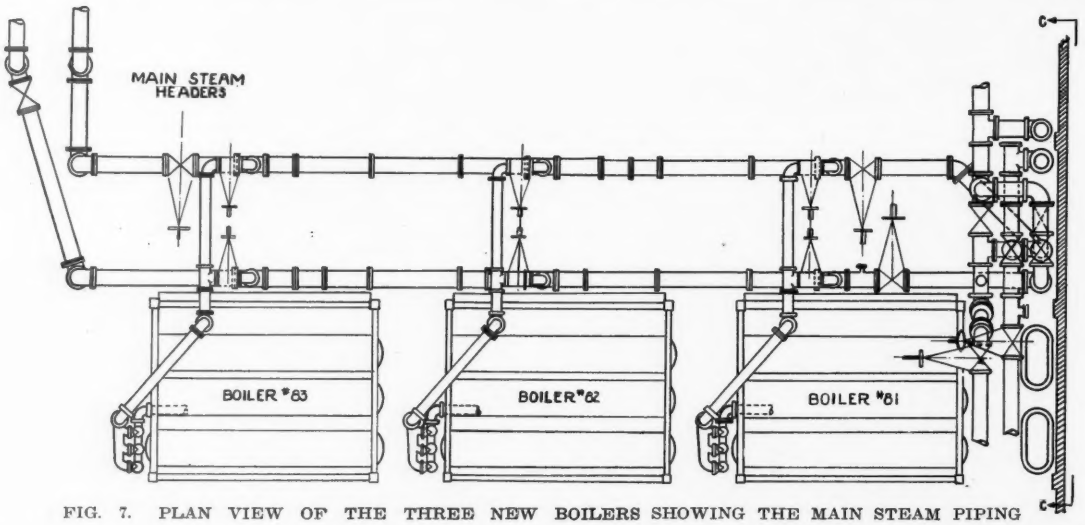


FIG. 7. PLAN VIEW OF THE THREE NEW BOILERS SHOWING THE MAIN STEAM PIPING

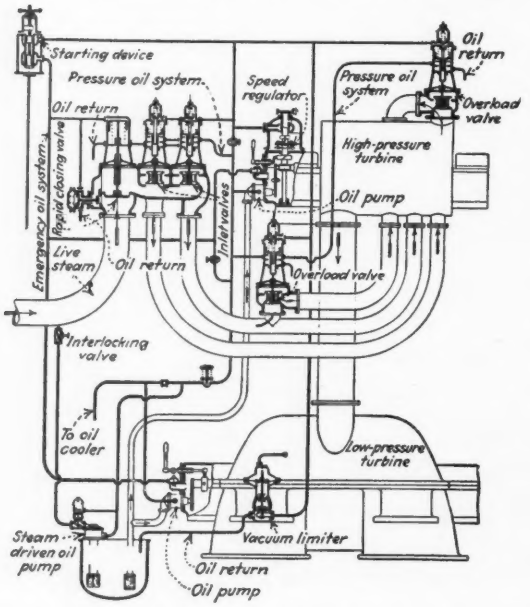


FIG. 8. DIAGRAM OF THE CONTROL GEAR FOR THE BROWN BOVERI TURBINE

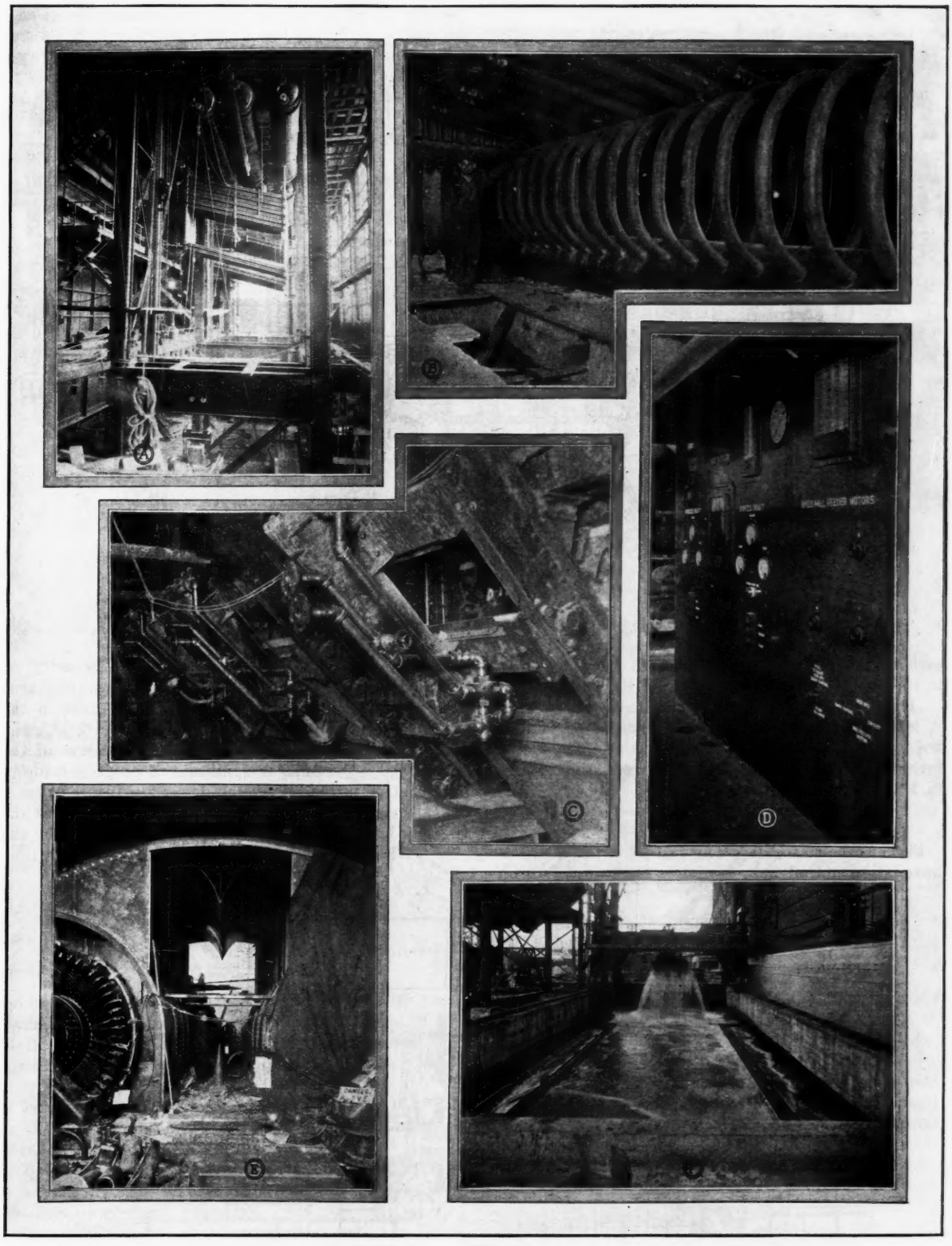


FIG. 9. SOME OF THE MANY INTERESTING FEATURES AT HELL GATE

A. A view showing the three new boilers under construction. B. Looking at the center header of the water screen. C. Two of the new boilers have inclined ash gates of this type. D. One of the boiler control panels. Each boiler is controlled from a panel of this type. E. The ventilating blowers of the Westinghouse generator are located between the two generators, as shown here. F. The new ash sluicing system in operation. This view shows the settling pits and grab bucket outside the building.

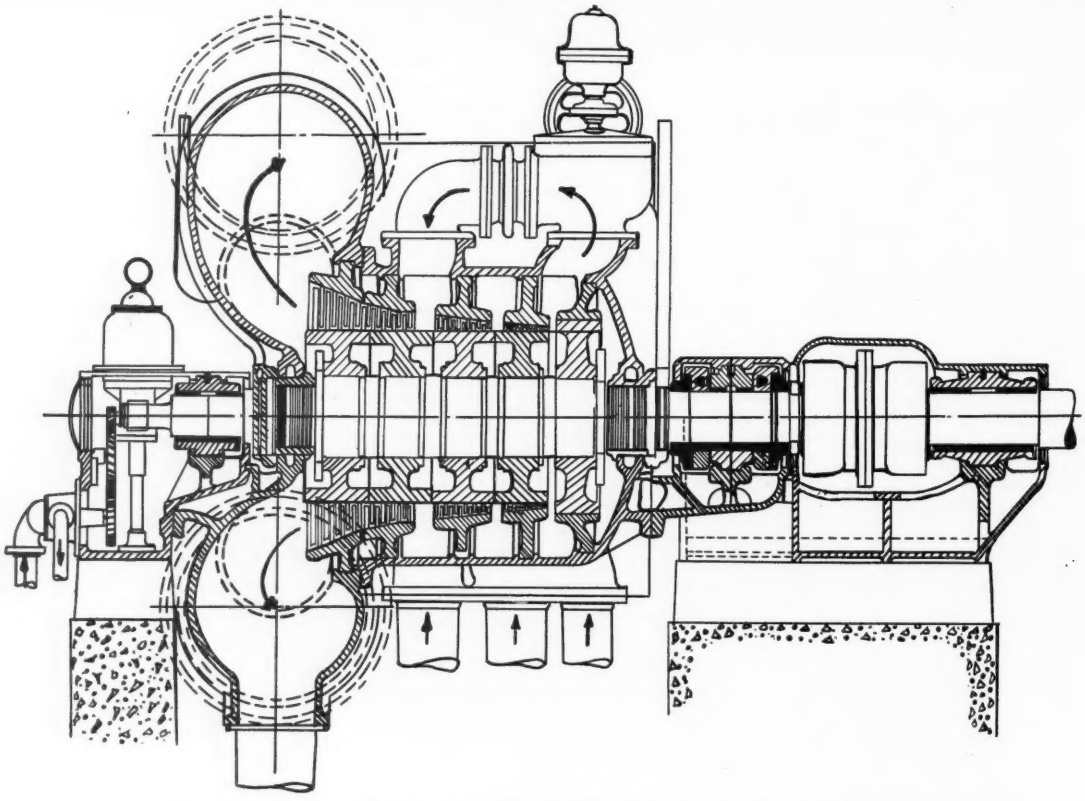


FIG. 10. HIGH PRESSURE CYLINDER OF THE BROWN BOVERI TURBINE

each row of boilers, are connected to the main trough to the settling pits on the outside of the building.

Due to the fact that the turbine room was extended, it was necessary to build a new settling pit and ash hopper as the old installation was on the site of the new turbine room extension. This new installation is shown in Fig. 9F.

Features of the New Generating Units

Perhaps the most interesting feature of the entire new installation at Hell Gate Station is the two new turbine generators, each of which has a rated capacity of approximately 160,000 kw. When it is considered that the first 35,000 and 40,000-kw. machines used in the initial installation at Hell Gate in 1920 were among the largest units built at that time, the installation of the new 160,000-kw. units is significant of progress made in the field of turbine-generator design during the past 8 yr. These new units are the largest in operation at the present time, although they are exceeded in size by the 208,000-kw. machines now being installed at State Line Station.

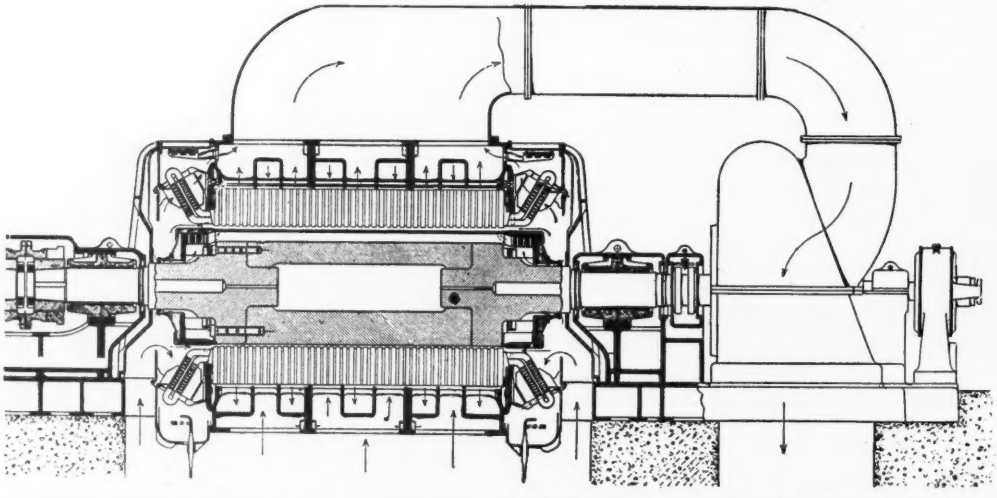


FIG. 11. SECTION THROUGH 88,200-KW. GENERATOR DRIVEN BY THE HIGH PRESSURE ELEMENT OF THE BROWN BOVERI TURBINE

Although of different make, the arrangement of the elements of the two machines is essentially the same. Unit No. 8, the first one which was placed in service is of particular interest because it is of European manufacture, having been built in Switzerland by the American Brown Boveri Co. Unit No. 9, which is rated slightly higher (165,000 kw.) than the Brown Boveri machine, is of Westinghouse Electric and Manufacturing Co. make.

In the design of these machines, the question of space was of great importance. The space available for unit No. 8 was 38 by 76 ft. and had been planned originally for a 40,000-kw. unit. This was the last unoccupied space remaining in the building. The initial requests for bids, therefore, called for the highest capacity generating units which could be installed in a space 38 by 76 ft. in area. Thus, today, a turbine generator of some 160,000-kw. capacity is installed in a space which, in 1920, was laid out for a 40,000-kw. unit.

In order to provide space for unit No. 9, the 165,000-kw. Westinghouse machine, it was necessary to build a 70-ft. extension to the turbine room.

Both units are cross compound machines consisting of a high-pressure turbine adjacent to a double flow low-pressure element, the steam from the high to the low-pressure element being carried overhead. Condensing equipment is the same for both units, being Westinghouse, double, two-pass radial type surface condensers, each with 137,500 sq. ft. of cooling surface.

Steam conditions for the new machines are 265 lb. and 300 deg. F. superheat. The high-pressure elements exhaust into the low-pressure elements at pressures of approximately 20 lb. per sq. in. gage when the units are operating at maximum load. Steam is bled from two points, one at receiver pressure and the other one at approximately the fourth low-pressure stage. The low-pressure elements exhaust to the condensers at an absolute pressure of 1 in. of mercury.

While the arrangement of the elements of the two turbines is similar, in details of design the machines are quite different. In the case of the Brown Boveri unit, the speeds of the high and lower-pressure elements are different—the high-pressure shaft operating at 1800 r.p.m. and driving a four-pole, 60-cycle generator, while the low-pressure shaft runs at 1200 r.p.m. and drives a six-pole generator. In the case of the Westinghouse unit, both the high and low-pressure shafts operate at the same speed, 1800 r.p.m. and both drive four-pole, 60-cycle generators.

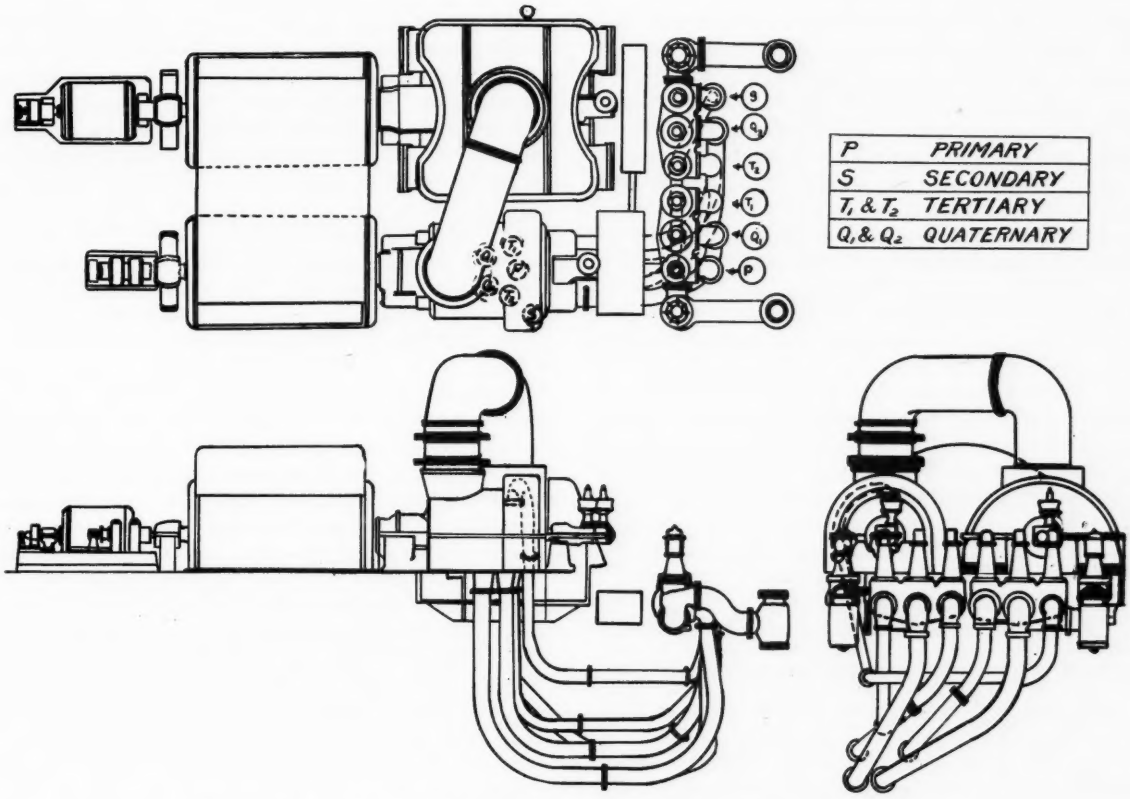
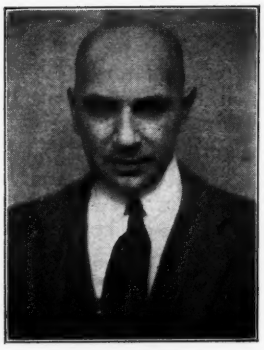


FIG. 12. PLAN AND ELEVATIONS OF THE WESTINGHOUSE 165,000-KW. UNIT

Arrangement of exciters and blowers on the two makes of turbines is also different. Because of the small space available, it was necessary to use a rather unusual arrangement for the ventilating system for the alternators. On the Brown Boveri unit, a separate closed ventilating system, incorporating a separate blower and cooler, is provided for each generator, one fan being coupled directly to the end of each generator shaft. Cooling air enters the alternator winding from below and passes out at the top through a large overhead duct connecting directly with the fan. After passing through the fan, the air returns to the generators through the

(Continued on page 648)

High Lights in the Trend of High-Pressure Turbine Practice



LANGERBRUGGE TURBINE CASINGS RUN DARK RED UP TO 850 DEG. F. BUT NOT LESS STRIKING IS THE DECISION TO RUN THE WITKOVITZ TURBINE AT 930 DEG. F.

BY

Geo. A. Orrok and N. Artsay

WITH THE EXCEPTION of a few small scale attempts to use higher steam pressures, the real industrial movement toward higher quality thermal cycles began soon after the World War and although the present day situation is full of promise for the future, we may take account of the results so far achieved. The work of the pioneer is always arduous but not less hard and certainly more strenuous is the present continuous effort in the gradual expansion of temperature-pressure limits for the thermal cycles.

First, however, in its ideal simplicity came the regenerative cycle of Ferranti, which has been responsible for the greater part of the heat saving effected in the large scale generation of power. The next step has been marked by the increased attention given to the condensing problem and the exhaust end of the turbines. Indeed, very real difficulties were encountered in the low-pressure end of the turbines and these are still troubling both the turbine manufacturers and the operating forces of large central stations. The slow progress in this direction is not spectacular and involves a tremendous amount of laborious research, experimentation and vexation; however, even if turbine blade failures have been common, commercial savings from improved machinery have been increasing and blade troubles and leaving losses are a diminishing quantity.

BOILER ROOM CHANGES IMPROVE TURBINE PERFORMANCE

About the time when the first enthusiasts for higher steam pressure began to put their ingenious ideas into practice, a sound step was quickly taken in the boiler rooms. The superheat was increased and steam temperatures rose to 700 deg. F. Moreover, the combustion problems were taken up and pulverized coal firing made its appearance. At this period, the demand for power in the United States was rising fast and soon the now obvious benefits of a larger scale for both boilers and turbines became understood. The unusual amount

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From 1911-1914, he was consulting professor of steam engineering, Brooklyn Polytechnic Inst., from 1918, graduate lecturer in steam engineering at Yale University and the last two years lecturer in steam engineering at Harvard University. With Professor R. H. Fernald as co-author, his book on the Engineering of Power Plants is regarded as an authority on power plant design. Mr. Orrok is a member of the A. S. M. E., A. S. C. E., American Institute of Mining and Metallurgical Engineers, Institute of Mechanical Engineers of London, V. D. I., fellow of the A. A. A. S. and a member of other scientific and engineering societies.

On January 1, 1929, Mr. Orrok severed his connection with the New York Edison Co. and opened an office at 52 Vanderbilt Ave., New York City, where he carries on his practice as consulting engineer.

NICHOLAS C. ARTSAY, now Principal Assistant Engineer to Geo. A. Orrok, was formerly Commander in the Naval Constructors Corps, Imperial Russian Navy. He was graduated in 1909 from the Academy of Naval Constructors and Naval Engineers, Cronstadt, Russia, after which he took the post graduate course in mechanical engineering in Emperor Nicholas' Institute of Technology, St. Petersburg, and then served in the navy until the revolution. During the war he was commissioned to study the battle behavior of ships of the line in the Baltic Sea on board "Sebastopol." During this period, he carried out extensive repair and alteration work on ships of the Baltic Fleet. During the Civil War, 1919-1920, he was Chief Naval Constructor of the Black Sea Fleet. He came to the United States in 1922 and was appointed test engineer at the Hell Gate Station of the United Electric Light & Power Co. In 1926, he was transferred to the New York Edison Co. and assigned to the office of Geo. A. Orrok, at that time its consulting engineer. Besides his specialty of designing and building warships, he is interested in all questions of mechanical and thermal equipment of power plants, thermodynamics and structural and physical properties of metals.

of engineering thought and daring required by this revision of standard sizes is not so apparent in technical literature as in the files of manufacturers. The main power generated a score of years ago in a small city power plant would hardly be sufficient today to drive the draft fans of a pair of modern boilers.

Thus, before the advent of high-pressure and high-temperature installations, much of the large improvement margin up to the Carnot cycle had been secured by better combustion, better load condition brought about by interconnections, by the regenerative cycle and by the greater average vacuum given by modern condensers. The first steps for increasing the overall station efficiency have been easy, the additional equipment or changes did not cost much per unit of installed capacity and the question of additional fixed charges was not so acute and definite. We owe much of the present progress of turbines and boilers to an error of judgment! Most of the technical progress was attained when the thermal efficiencies were the criterions of good economy and money was flowing freely into refinements. The policy of commercial efficiency which has now taken its proper place not only brought back many discarded types of equipment, suitably changed, of course, but revised also the cautious conservatism which is so necessary for standardized production.

Practically the Entire Pressure Range Being Investigated

Theoretical studies for the betterment of steam cycles quickly indicated that the practical limits for the best efficiency of the pure Rankine cycle are reached at a relatively moderate pressure and that an increase in total temperature of steam held more promise. Simultaneously, it was also noted that multistage bleeding is the more effective the higher is the pressure. A cautious but satisfactory advance was made using steam at 375 to 400 lb. per sq. in., 725 deg. F. with four-stage bleeding, while other experimental advances were made at Langerbrugge (750 lb. per sq. in., 850 to 900 deg. F.), Edgar (1200 lb. per sq. in., 730 deg. F.), Lakeside (1400 lb. per sq. in., 725 deg. F.). But these installations were of less significance than the decisive results obtained at Philo, Columbia, Klingenberg and Crawford Ave., (550 to 600 lb. per sq. in., 725 deg. F.) which established another standard of high-pressure operation. Other experimental plants which have blazed the way, may be noted, such as Borsig (900 lb. per sq. in., 800 deg. F.), Siemens-Schuckert (2500 lb. per sq. in., 750 deg. F.) and Witkovitz (1700 lb. per sq. in., 932 deg. F.).

Properly the problem of the most economical steam pressure belongs to the boiler room because the high-pressure turbine very quickly attained a position of reliability and simple ruggedness so that today the high-pressure end is probably more dependable than the low-pressure exhaust end. The efficiency and reliability of high-pressure turbines is much improved with the amount of steam flowing through them. Due to the low specific volume of high-pressure steam and the necessity for full circumferential admission the design depends much on the amount of steam passing the turbine. For small amounts of steam, the Brown-Boveri turbine at Langerbrugge and the Ljungstrom types are the best but equally good results were obtained by Erste Brunner (Loesel), Escher-Wyss and their licensees. The most troublesome problem is the blade size. The Escher-Wyss turbines at Siemens-Schuckert plant have blades ¼ in. high for 2500 lb. per sq. in. pressure, while some of Erste Brunner turbines have nozzle orifices as small as 2 mm. (less than ⅛ in.). The increase in blade size can be attained by reducing the adiabatic drop (velocity) per stage at the cost of increasing the number of stages, and reducing the wheel diameter. For a small amount of flow, the high-pressure turbines resemble more a jeweler's chef d'œuvre than the work of a mechanic; however, for large amounts of flow these difficulties disappear and the turbines are quite simple, for instance the General Electric Co. turbines at Boston and Milwaukee.

Special Alloy Steels Used for High Temperatures

The larger the size of the turbine the more difficult is the construction of the casing and glands. Special alloy steels are necessary here. It was astounding to see the Langerbrugge Brown Boveri turbine casings running dark red up to 850 deg. F. but not less striking is the decision to run the Witkovitz turbine normally at 930 deg. F. Considerable change in the elastic constants takes place at such temperatures and the calculations of vibrational frequencies for the shafts become uncertain. Special care is required in the design to eliminate thermal stresses which can be quite serious because of the steep temperature drop along the steam path. Special mantles around the stationary blade casing with steam between are frequent in the European designs. Ingenious designs by Prof. Roeder (Siemens-Schuckert), eliminate the high-pressure gland; however, with the growth in the size of the high-pressure units, it will be possible to construct a double flow, high-pressure barrel with central admission of steam and thus this awkward item will be eliminated. Actual experience in this country up to 1400 lb. per sq. in. does not indicate any special troubles with this gland but at Edgar and Lakeside the temperatures are not very high.

Steam Reheaters Widely Used with High Pressures

There are very few straight high-pressure plants in operation and in the majority of plants where high pressure is used, the high-pressure turbines are superimposed on the standard equipment; they are termed "reducing valve turbines." It is thus possible to run them at constant load and the speed governor does not present any particular difficulties. It is different with some industrial plants using process steam. For instance, the Witkovitz turbine is built as a double-pressure turbine, using high-pressure steam up to the present high-pressure boiler limit of generation. The additional steam necessary is taken from the old waste heat and regular boilers of medium pressure; moreover this turbine is bled in two points for process steam, thus the governor is set on the medium pressure steam supply. When the high-pressure boiler plant is increased to the full extent, the governor will be connected to the high-pressure steam supply and the medium pressure waste heat steam will be used in whatever quantities available.

Due to the low heat content and low entropy of high-pressure steam, the steam reheater is an integral part of any high-pressure installation. Reheating in boilers is known quite well in this country but abroad they balk at so much extra piping, consequently went to steam

reheating by live high-pressure steam. Sometimes it is done in two stages: in the first stage, the high-pressure steam is condensed and in the second there is an exchange of superheat; sometimes the whole main bulk of steam passes through the second-stage reheater. The Witkovitz plant steam reheater consists of coils of large diameter tubes inside of which run small diameter tubes with high-pressure steam, they are thus surrounded by the steam to be reheated. These reheaters are very compact, can be put close to the turbine and their steam volume is small enough not to permit overspeeding the turbine with the load off.

Feedwater Treatment Important for Turbine

The question of pure feedwater in high-pressure plants concerns the turbines as well as the boilers. Many chemical compounds present in the boiler can be volatilized or carried in molten state through the superheaters into the turbines when, with the reduction of temperature, they are deposited on the turbine blading. Anderson's report* on experience with 1400 lb. per sq. in. at Lakeside, mentions the necessity of periodic washings of the high-pressure unit to restore its flow capacity.

The present technical position attained by the high-pressure turbines indicates that the best results will be obtained in large installations and the difficulties of construction and operation will be the less the greater is the amount of steam used in the turbine. Up to 750 deg. F. total temperature of steam, the high-pressure turbine of sensible capacity will be more rugged and more reliable than its medium and low-pressure neighbors. Special designs are required for higher temperatures and, while the question of temperatures is a great deal more serious than the question of pressures, still we may confidently expect to see turbines running normally at 1000 deg. F. total steam temperature and at pressures up to 2500 lb. per sq. in.

From the standpoint of economy, the high-pressure turbine is probably the least expensive and least cumbersome main item in the whole high-pressure plant considering the cost per kilowatt of capacity and the selection of the most economical pressure is hardly affected by the turbine question. It is entirely a matter of boilers and of the station load factor.

Americans and Europeans Coöperating on Research

A review of the high-pressure steam turbine development would be incomplete without mentioning the research problem into the properties of steam which has been under way for the last eight years. The practical work of designing high-pressure boilers and turbines necessitates exact knowledge of the relationship between pressure, temperatures, specific volume, entropy and total heat of steam. This research has been extended to include the range between ordinary temperatures and pressures and the critical point, going as high as about 1000 deg. F. Coöperation has been secured between the work in this country and that of the European investigators, which it is hoped will result in international agreement. With the increased refinement of turbine and boiler designs, more strict requirements and keener competition, other aspects of steam behavior have been emphasized and there has been a considerable study of the metastable phases of water and steam which has been brilliantly summed up by Professor Stodola. It is probable that much more attention will be paid to these unstable conditions which occur in the changing of state of the fluids used for power production.

*See Power Plant Engineering, Feb. 15, 1928, page 229.

P. G. & E. Co. to Have First Double-Deck 1200-lb. Units

SEVERAL UNUSUAL or new features will be incorporated in two steam turbine generators which are to be added to the generating facilities of the Pacific Gas and Electric Co., San Francisco. Two machines, each rated at 50,000 kw., the first of the new double-deck compound type, will be the first high-pressure turbines on the Pacific Coast. They are to be installed in Station A of the company, as noted in the May 15 issue of Power Plant Engineering.

This installation, it is claimed, will be one of the most efficient in the world, the result both of employing 1250-lb. boilers and using natural gas as fuel. Each main 1200-lb. turbine unit, of General Electric manufacture, consists of a high-pressure element operating at 3600 r.p.m. and a low-pressure element operating at 1800 r.p.m. The turbines, rated at 50,000 kw. each, are to be suitable for a maximum output of 62,000 kw. Provision is made so that the low-pressure turbine can be operated from the high-pressure boilers with the high-pressure turbine shut down.

New type of construction will be used, in that the high-pressure turbine and generator will be mounted on top of the low-pressure generator, thereby saving the foundation and the floor space ordinarily required for the high-pressure turbine. The result is a compact unit and, since working out the design details, this type of construction appears even more advantageous than when first proposed.

In addition to the main turbines, two General Electric auxiliary turbines are included for driving the boiler feed pumps. These pumps, used with high-pressure boilers, absorb considerable energy, and therefore these turbines are much larger than usual. They are of the two-unit type, composed of condensing and noncondensing elements. The condensing element is coupled to one end of the pump and takes steam from the present 300-lb. boilers; the noncondensing element is coupled to the other end of the pump and takes steam from the cross-over between the main turbines. This arrangement permits the two elements of the turbines to be operated at times independently and at other times together, so as to maintain at all loads the most economical heat balance in the installation as a whole.

Starting July 15, The Commercial Standards Monthly, which summarizes progress in standardization and simplified practice, will appear as a standard size printed magazine, subscription $1 a year, to Superintendent of Documents, Washington, D. C. S. F. Tillman has been appointed editor. He has been on various papers, was managing editor of Army and Navy Magazine and, recently, with the Division of Simplified Practice of the Bureau of Standards which will issue the new monthly.

Engineers *and* Architects Must Co-operate to Build Beauty *into the* Power Plant

By W. A. Shoudy
Consulting Engineer

TRUE APPRECIATION of beauty requires education, not because there are arbitrary standards but because beauty implies an accomplishment above the average. Our judgment is based on the failures of ourselves and others. The engineer's beautiful engine is greasy and dirty to the artist, because the artist does not know of the difficulties that have been surmounted in its design; the architect's beautiful building may seem impractical and uneconomic to the engineer because he has failed to show the engineer the economic need of the building. Fundamentally, the engineer and the architect are working for the same result, although, because of early training, one may overemphasize the aesthetic and the other the economic phase of the problem. Only as the two professions work together will our structures become beautiful in every sense of the word.

After all, the architect should be fundamentally a structural engineer. The builders of some of the ancient cathedrals were known as engineers, not architects and only one hundred years ago some architects were recorded as surveyors.

Development of Architecture

The engineer's criticism of the architect is that the latter has not only forgotten that he is an engineer but has also overlooked the fact that within the last 75 yr. the engineering basis of architecture has changed. We have different materials to work with and different conditions to meet, requiring a new type of architecture, which is based, nevertheless, on the same fundamentals of beauty in design.

Architecture originated in the need of protection, first in the home; later, it developed into the erection of a tabernacle for the protecting deity. Large structures were first of a religous nature and were made of native materials to suit local weather conditions. In sunny Greece, where there was no snow load, we found flat-roofed, open-sided buildings; in the cold north, the roofs were pitched and windows and doors were provided to keep out the cold and inclement weather.

Each engineer-architect sought to use less and less material; thus, largely by trial and error, buildings developed into the proportions we now call beautiful. The Gothic arch is not primarily a thing of beauty but an engineering achievement for the support of a steep-

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Among the positions which he has held are those of assistant mechanical engineer of the J. G. White Engineering Corp.; power engineer of the American Sugar Refining Co.; superintendent of steam plants and advisory engineer for the Adirondack Power & Light Corp.; advisory engineer for the General Engineering and Management Corp., and consulting engineer for the Bailey Meter Co. and M. H. Detrick Co.

He has contributed a number of articles to the technical press and has been active in the engineering societies. He is a member of the Publication Committee of the American Society of Mechanical Engineers and of the Prime Movers Committee of the National Electric Light Association.

pitched roof. Every stone of an ancient or medieval cathedral is cut to meet structural engineering conditions.

Ornamentation came later, with carvings to relieve long, unbroken lines and color to break the monotone of stone or wood. But even with color or carving removed, these old structures remain beautiful because they are sound engineering achievements.

The colonial architecture of this country is another example of the economic aspect of beauty. With only wood, stone, a small amount of brick and a few skilled artisans, the colonist developed simple, economical but beautiful buildings.

The beautiful moldings that the architects copy from ancient buildings are those that have survived the

FIG. 1. AMSTERDAM STATION, AN OUTSTANDING EXAMPLE OF GOOD ARCHITECTURAL TREATMENT

weather conditions, the action of sun and frost. These are not made up of circles and straight lines but of stream-lines of great beauty. The railroad car axle is a development of repeated failures and reinforcements, until now it is of stream-line proportions that delight the eye of the artist. Stone columns are beautiful only when of the correct proportions for strength and the steel column is beautiful only to the skilled constructor whose eye can estimate its strength. Encase it in plaster and there is no beauty till the mind's eye, seeing it as stone, is satisfied that it is thick enough for strength but not wasteful of material.

Beauty is essentially an engineering matter and engineering is not perfected unless beauty is satisfied.

Structural Steel Leads to a New Architecture

With the coming of the mechanical age and the concentration of population in our cities, a demand was created for buildings with more floors. Soon the limit was reached for wood and masonry but the introduction of structural steel made the skyscraper possible. Architects at first did not fully realize that they had a new material to work with that upset the former basis of structural engineering. They hired engineers to design the skeleton and then draped it with facades copied from classic designs. The first results were monstrosities but a new architecture has been developed and many of our buildings now are marvels of engineering and aesthetic achievement. The more beautiful buildings have attracted higher rentals and beauty of design has received an economic endorsement. Beauty in some manufacturing buildings has also had its economic justification in the advertising value of the buildings.

Power House Is a New Type for the Architect to Handle

Individual power houses have been with us hardly 75 yr., for the first engines were installed in the factory buildings and the central station is a product of this generation. These buildings have offered the architect a problem in design that is totally new. The public has condemned the engineer for not creating beautiful structures in a generation though architecture has taken centuries to develop.

A home, a church or a public building may be arranged to suit the architect's ideas of masses or use of material. Slight changes in the dimensions of a room are unimportant and, if columns are needed in a cathedral, they reduce only slightly the seating capacity. A factory for small machines is designed with a column spacing that will be most economical of steel and as many windows may be installed as the column spacing will permit. We can't run a column through a boiler setting, however, nor can we place windows in a coal bunker.

The building for a power house is only a shell covering one machine for, after all, the boiler or turbine is only a part of a steam-electric machine. Hence the parts of this machine must first be efficiently arranged and then the house built only to house the machine. This house must be weather-proof, light, well-ventilated and with ample working space. Floor and roof heights must be determined by operating conditions; parts of the machine cannot be shifted to permit of uniform column spacing; frequently the roof lines cannot be continuous.

Engineer and Architect Must Each Give Way a Little

Such a specification is enough to break the heart of any architect who does not realize that he is dealing with a type of building that is new to the world. The engineer was the first to want beauty in his structures but the architect failed to help him without greatly increasing the cost of the structure. Consequently, either unadorned buildings were built or simple ornamentation by limestone trimming or ornate lamps was the only attempt at beauty.

The engineer's heart was in the machine and, since the architect could not help him, he ornamented the turbine room with red tile floors and white tile walls and found that the spirit of his men was improved, because they were proud of the plant. Then he began to plant grass seed and shrubs and he found that beauty paid in improved morale.

It is not the engineer's fault that the public does not call his power plants beautiful. His training in beauty is only that of the general public. Instead of recognizing his limitations in design, the architect has laid down impossible conditions. But the engineer and

the architect are slowly coming together. Our steam power plants are growing more beautiful. There is less spotty ornamentation and a closer study of the relation of masses. Both the engineer and the architect have had to compromise and such compromises will eventually lead to real beauty.

Often the engineer has been at fault in rigidly dictating the building dimensions: not a foot may be added to length, breadth or height and no window may be shifted nor changed in size. There is no reason for such specifications. If walls are to be unbroken, the only relief that the architect can offer is to use high-quality brick and struck joints or elaborate cut stone trimming. But by set-backs in the walls, the masses may be broken up with beautiful effects. Such set-

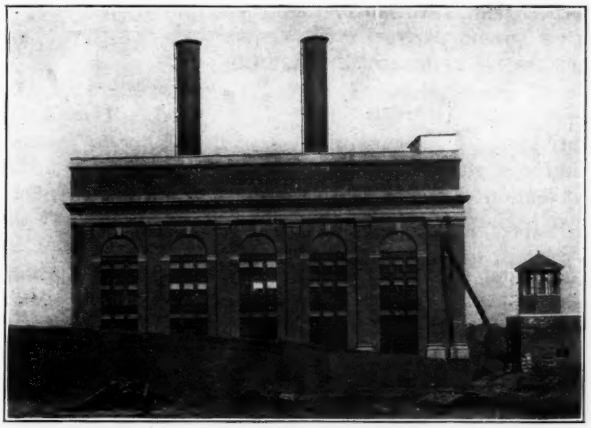

FIG. 2. SLIGHT ENGINEERING COMPROMISES WERE MADE AT WHIPPANY STATION TO MEET ARCHITECTS REQUIREMENTS

backs may lengthen one room two or three feet where additional space is not required but they may permit the architect to use a cheaper brick with a money saving greater than the increase due to the larger building.

We are accustomed to estimating building costs in cents per cubic foot. It is a convenient method but one which may mislead. Factory and office buildings may be compared on this basis, yet such comparisons for power houses are seldom satisfactory. The major part of the building steel is for the support of machinery and coal bunkers and the total weight remains substantially the same regardless of the size of the building, if the machinery is unchanged. An extra foot of length in the building affects the steel by a negligible amount, possibly adding a foot to two thin walls and one roof and sometimes to the foundation. To estimate the increase in building volume and to multiply that by the assumed cost per cubic foot gives an increase far beyond its true value. If the increase in cost must be figured, it must be figured in detail or not at all. We must be careful not to charge the architect with increasing the cost of the building by changing the dimensions. He may be cheapening it by making a cheaper material possible.

Amsterdam Station of the New York Power & Light Corp. (formerly Adirondack) Fig. 1, always comes to mind when discussing this subject. It is an example of what the architect may do when given a free hand. It is probably the first truly beautiful power station in this country. The use of anthracite made possible the selection of white concrete simulating fine white marble. The setting in the Mohawk Valley added greatly to the beauty. If any criticism is to be offered, it would be first because of increased expense. The advertising value to this company, however, has not been negligible. A second criticism might be that some engineering principles were compromised for greater beauty; some have felt that the classical type of architecture does not represent power. But the massive scale somewhat softens this criticism. It must be remembered that this is a pioneer station, therefore any criticism is somewhat of a carping nature.

Whippany, N. J. station of the Jersey Central Power & Light Co., Fig. 2, is an example of slight engineering compromise to meet the architect's requirements. The architect worked under the disadvantage of creating a design quickly, in order not to hold up for a single day the progress of the steel draftsmen. The boiler house was lengthened 3 ft. to provide a set-back on the right facade (this extension later was invaluable) and certain sections of the coping were built larger than otherwise necessary. Windows were all of standard dimensions. The trim was of precast stone and the

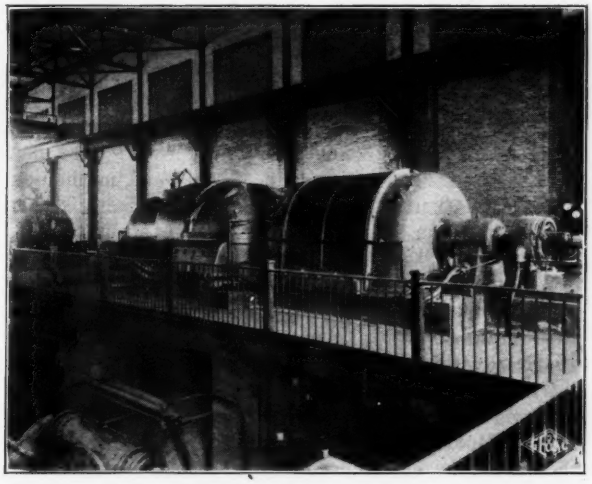

FIG. 3. THIS TURBINE ROOM WAS APPROPRIATELY DECORATED WITH RED TILE FLOOR, BUFF, GLAZED-BRICK WALLS AND BROWN AND GREEN TILE TRIM

brick was the cheapest quality obtainable. It is unfortunate that later changes in coal-handling equipment marred somewhat the architect's conception. The additional column is omitted at the left because that wall is temporary.

The turbine room of this station, Fig. 3, was designed to encourage cleanliness. The floor is of red tile and the walls are faced with salt-glazed brick in buff, with a brown border. Green tile in the corners add a touch of color. These walls can be cleaned more easily than the customary white tile, are lower in first cost and present an artistic appearance.

The proposed boiler house shown in the headpiece illustrates what the architect can do with a simple building. Floor plans, floor and roof elevations were given to the architect with approximate location of windows; walls were to be not over 12 in. thick, carried on

the steel. Standard-dimensioned windows were used and set-backs were obtained by carrying an 8-in. wall above, supported by the lintels of the windows. The only expense added by the architect is that of the extra labor of laying brick over that for an unbroken wall. Because cheap brick can be used, however, the actual cost is less than with a selected brick without architectural treatment.

Is it too much to expect that we can eventually get beauty in power stations? We engineers want it because we want to be completely satisfied with our creations. We can't waste money and continue to be engineers, yet we feel that, except in rare cases, the architects have failed to grasp our problem.

The engineer cannot alter his basic design but he should be sure the limits he sets are sound. Let him lay out his machine, set a maximum and minimum size for each part of his plant and give some tolerance for the size and location of the windows and doors. Then let him leave the architect to the development of an original design. For a time, the engineer may need to compromise with the architect but, as each learns more of the other's problems, compromise will become unnecessary.

The Architect's Idea of Power Plant Beauty

IN DESIGNING A BEAUTIFUL POWER PLANT, HE IS GUIDED BY CERTAIN FUNDAMENTAL PRINCIPLES; ENGINEER'S DESIGN MUST BE FLEXIBLE ENOUGH SO THAT THEY CAN BE APPLIED. BY HOBART B. UPJOHN

WITH MAN'S appreciation and realization of a Creator and the desire to show Him deference and love and to appease the anger of an unknown force, probably came the oldest form of man's intense desire for expression in art and the first elements of a constructive form of beauty. It was first realized in the beginning of man's philosophy of life and its relation to creation. When we consider that this impelling force was the motive power back of the greatest architectural achievements, from that very primitive time almost, we may say, to our own day,—a period variously estimated at from 25,000 to 3,000,000 yr.—we can realize how young is our generation and the use of mechanical force in relation to the life of mankind. There is born within us, even in the crudest savage, an unsatisfied desire and ambition for beauty. This unquenchable fire, God-given in its initial impulse, evidences itself in every nation and tribe of the world and in every possible and conceivable form.

Even within the past 100 yr. and, practically, within the memory of living men, the highest speed at which man was capable of traveling was the speed of the horse. During these 100 yr. we have advanced from the horse through the railroads, machine shops, electricity, telegraph, telephone, the automobile, the radio and the airplane. Today we stand with millions of years of tradition in art and architecture behind us and a hundred years of the gradual harnessing of mechanical power. Man has studied what constitutes beauty, largely influenced by its structural meanings. I say influenced, although unconsciously, because in the very nature of things it is governed by the essential elements of strength. Civil engineering, the first sister of architecture to have a recognizable place with its elements of birth in the great Gothic periods, has for a thousand years struggled hand in hand against the static forces of gravity in the production of the greatest masterpieces in architecture the world has to this day witnessed.

One hundred and twenty years ago, man discovered a black mineral capable of producing a much more intense heat than any material previously at his command. It is strange to note that man's first conception of a creative being to which he paid unwitting and unknowing homage was fire, little realizing that a great power, ages and ages after, would come from that very element of heat. With the discovery of coal and the utilization of the expansive force of steam, great changes in the world's form of living were produced. With the invention of mechanical means of power came mechanical perfection now measured to the ten-thousandth of an inch. With its discovery came a mad rush for invention and progress and one of the saddest things in the memory of our generation has been the heedless destruction of beauty in attaining speed. River fronts everywhere have been sadly abused; ash, coal, waste product and paper have been dumped without regard and rivers polluted, and changed from their courses; the glorious inheritances of millions of years so mutilated and destroyed in this mad rush for power as to stand as running sores of civilization, a disgrace to mankind of today. There has been practically no heed taken of the sense of order, neatness, arrangement, or aesthetic expression of the buildings which grace these river fronts. Our engineering schools have turned out thousands of men but, if we look at the curriculums of the schools, not one word for the many years that a student spends in studying his profession is said about beauty in its relation to mankind.

EVEN THOUGH MAN NEGLECTS BEAUTY, NATURE NEVER DOES

Look about you and you will realize that nature never neglects this element. Scar a hill and nature will endeavor to heal the scar with the beautiful forms of plants and flowers. A landslide occurs and the outline left in the remaining crags is beautiful. Nature comes forth in verdure every spring in a new vestment of beauty and even the loss of leaves exposes wonderful shapes and forms. Man alone appears to be the greatest force opposed to beauty, yet the meanest peasant and the highest king yearns, at heart, for this intangible thing.

It has even been preached against in the technical schools as a thing effeminate, to be shunned as impractical and opposed to the basic elements of engineering efficiency. In other words, this element of beauty is too effeminate to stand beside this new-born, essentially masculine mechanical power, utterly forgetting that, thank God! there is such a thing as masculine beauty.

Today, however, I believe there are distinct evidences

of the birth of a new period; a period of Renaissance in engineering, a period of appreciation and understanding. It is becoming more and more apparent that the efficiency of our workers depends largely upon the way they are housed and clothed and upon the conditions under which they work and play; that the elimination of all beauty from the lives of the mechanic and the laborer is accompanied with the elimination of interest and ambition, characteristics which we are more and more coming to realize are absolutely essential to the highest efficiency and ambitions which we would attain.

Is Beauty Opposed to Efficiency?

Is it true that beauty and efficiency in mechanical buildings are opposed to each other? I am positively convinced that they are not. Such great artists as Joseph Pennell and Jonas Lie have caught in their paintings and lithographs the essential beauty of mechanical manufactories. They have proved to us that it is even possible to recognize and utilize the beauty of steam, vapor and smoke. If, then, the artist can catch the poetry and beauty of these intangible things, is it not reasonable to believe that the architect may grasp and infuse into the building the inherent beauty of expression of which these buildings are capable?

It has been said and, in fact, there has existed, an entire variance of opinion and a deplorable lack of sympathy between the engineer and the architect. On the one hand, we have a practical man who sees only the efficiency of his plant and figures the entire installation according to mechanical conditions. On the other hand, the architect, trained in traditional expressions, is likely to see only such forms as he has been trained to recognize as essential to beauty and architectural expression. Yet, if we look at it another way, both professions are essentially constructors and if we consider for a moment, it seems inconceivable that there should be such a lack of sympathy between the two professions so closely allied and with such similar ambitions.

It is surely necessary that there be mutual understanding and confidence. It is essential for the architect to realize that the relation of parts laid down by the engineer must be, of necessity, adhered to. On the other hand, it is absolutely essential that the engineer realize that there is a great deal more flexibility in his plant than he at first gives it credit for.

The engineer is likely to figure his floor construction perhaps first on the minimum amount of steel required to cover a given span or possibly he may be governed by the minimum distance required by some machine. It has been my experience as an engineer that often a girder will be used for a given span, not because it is the lightest weight that can be employed but because the sizes adopted are more available and a foot or so added to its span would not in the least decrease the allowable floor load below what is required. This is only one example of a method by which the engineer may be more flexible. A foot or so on the heights of columns, the extending of a parapet, a possible shortening of a column or even the treatment of a column are other changes which may be made in the engineer's original plans which will oftentimes solve a difficult architectural expression.

It is for the engineer to realize the basic principles of the architect and to remember that he is dealing with a man who must feel, without necessarily a definite reason, the proportions of his buildings. The architect is trained to be sensitive to line and proportion—the very essence of his training produces an organism that is difficult for the engineer with his practical training to understand, while the architect must, in attacking a problem of this type, make himself free enough, flexible enough and inventive enough to produce forms for the natural interpretation of the problem before him.

Engineer Should Learn Four Principles That Guide the Architect

Three or four principles should be recognized by the engineer as essentials. We have first the principle of mass. The study of mass is the study of bulk in relation to other bulks or masses. We may have, in other words, a series of purely rectangular buildings in relation to each other, or rectangular forms without regard to dimensions or proportions, on the same building, but underlying the whole principle of architecture runs a definite relation which these masses must have with each other if beauty is to be attained.

The second principle is what we know as proportion. Proportion is relation to the dimensions in a single

Hobart Brown Upjohn, architect, New York City, is a member of a family that has practiced architecture in New York for three generations. He graduated at Stevens Institute of Technology in 1899 with the degree of mechanical engineer. In 1902, as assistant principal of the School of Architecture of International Correspondence Schools, he compiled a large part of the course in architectural engineering. He is a member of the American Institute of Architects, Architectural League of New York, has won honors in the International Exposition at Turin, Italy and recently received a prize in a competition held by the Christian Herald for a church of limited seating capacity.

Mr. Upjohn has designed many buildings throughout the country. These include the new buildings of the North Carolina State College at Raleigh, the large high school at Roanoke Rapids, N. C., the buildings for St. Catherine's School for Girls at Richmond, Va., and other educational groups. He also has designed such buildings as the United Hospital at Port Chester, N. Y., the Public Library at Rye, N. Y., the Village Chapel at Pinehurst, N. C., the First Presbyterian Church at Greensboro, N. C. Among his commercial buildings and power houses are the Whippany Station at Whippany, N. J., and the Port Inglis Station at Port Inglis, Fla.

mass or in different masses as they relate to each other. It is a refinement of the first principle involved in mass.

The third element is scale. Scale may be defined as the relation of the size of sub-division of a mass to the mass itself and the relation of its individual elements to the elements of another mass. For example, one may have two masses beside each other which have been first adjusted in position to give proper balance as far as bulk goes. The masses may then be proportioned so that they supplement each other in shape, which introduces the second element of beauty. Thirdly the masses may be so sub-divided by horizontal and vertical lines as to be in scale with each other and to look as if they belonged together. This then illustrates the first three principles of architectural design.

The fourth principle of architectural design is what is known as a group relation of openings to the surrounding form. It is the proportion of voids and solids and it is recognized by everyone in the framing of a picture or in the placing of an illustration on a page.

The architect is trained in the elements of planning. His first principle in laying out any building is law, order and logical sequence of requirements. If this element of planning is of utmost importance to the residence, the bank, the governmental buildings, surely the same elements of law and order must obtain in the engineering building. It is not that the architect lacks appreciation of the ambition of the engineer but I am convinced that it is because he lacks the knowledge and has not been informed of the engineer's ambition and requirements. He is likely to receive the engineer's plan with its required mechanical sequence of rooms and machines with little explanation of the "why and wherefore," therefore he plans according to the principles in which he has been trained instead of recognizing the principles to which the engineer must adhere.

What Does Beauty Cost?

Another fault, which is so often the cause of many failures, is that the engineer as a rule bases the cost of his building on the cost per cubic foot. Often a change in length or width or height is accompanied by little additional expense. I can remember adding about 14 per cent more building at an additional expense of 11 per cent where the spans were not increased nor the number of elements changed. It is not true that cost varies on a cubic foot basis and sometimes it is hardly just, where changes are made in the cubical content, to claim that these changes involve great additional expense. Beauty is one of the elements of efficiency and the expense to obtain it, within reason, is certainly justified.

Now let us consider for a moment the actual design. Obviously it is impossible to state that any present known architecture or future architecture may be the only architectural style in which power houses should be built. In my opinion the problem should be attacked from the viewpoint of the problem as it exists, not necessarily interpreted into and forced to conform to any preëstablished style. A power house should be a power house and should express that thought architecturally. It is proper that architecture should, if possible, express the use of the building so that a machine shop would be architecturally a machine shop or a power house a power house.

We are today endeavoring to solve problems according to the modern interpretation and the essential elements of our own day. New styles and thought are springing up, not alone in our country but in such countries as Norway, Sweden, Denmark and Germany, which give promise of a new style more rugged, more simple than the traditional and more expressive of the spirit of our own severe and mechanical age. The so-called modern style expresses the directness, the frankness and sincerity which is the ambition of the artist of our day. Straight, plain surfaces, set-backs, buttresses are certainly more sympathetic to the expression of power than the Grecian temple.

Architect Should Be Retained at Beginning of Work

Permit me to suggest that the proper time for the retention of an architect is in the very beginning of the plans, even if in a consulting capacity only. If it were possible for the engineer to lay out his plant in a preliminary way without regard to the structure, depending upon the structural engineer and the architect for the determination of column centers, girders, and so on, but all kept in the preliminary stage or we may say, a state of flux, then, when all were agreed, a mutually satisfactory skeleton plan could be issued to the engineers and the architect. The three could then proceed with little or no interference or delay to complete the plans simultaneously at a great saving of time.

The architect is an expert on plan and design. He brings to the building problem not only a sense of beauty as his contribution to the solution but an intimate knowledge of styles and materials and a practical judgment in their selection.

We are today endeavoring to express our times in the essentials of our buildings. This is not a new thought; it is one of the basic principles back of architecture from the beginning of time. One can almost sense the culture and habits of a people by studying their buildings and today we are in a position to express the very thought of power, simplicity, directness and truth in the buildings of our age. There is no reason, with proper sympathy and selection of material, why the engineer and the architect should not work shoulder to shoulder in producing the greatest buildings of this type the world has ever seen, embodying all the beauty, strength, power and majesty that this great branch of our modern age is capable of expressing.

Arrangements for the reception of 100 of Europe's most distinguished engineers and scientists who will arrive here during the summer en route to the World Engineering Congress at Tokio, have been placed in charge of Roy V. Wright, president of the United Engineering Societies, as chairman of the New York Reception Committee, according to a recent announcement by Maurice Holland, executive secretary of the American Committee of the Congress, of which Dr. Elmer A. Sperry is chairman. With Mr. Wright on the New York Reception Committee are Bancroft Gherardi, J. V. W. Reynders, F. R. Low, C. O. Mailloux, A. W. Berresford, H. Foster Bain, F. L. Hutchinson, Calvin W. Rice and George T. Seabury. Offices will be set aside for the visitors in the headquarters of the American Committee of the World Engineering Congress, 29 W. 39th St., New York.

Analyses of Electric Utilities Costs

COMPARISONS OF COSTS BASED ON VARIOUS FACTORS SHOW WIDE VARIATION FOR TEN NEW YORK COMPANIES. BY ROBERT T. LIVINGSTON*

IN ANY BUSINESS, much can be learned from a study of the various companies engaged in that business. The electric light and power industry in the various sections of the country can obtain much valuable information by comparing their operation with the operations of other utilities in other parts of the country. The different operating companies are differently organized and managed, are of varying sizes, charge different prices for the electricity which they sell and pay different amounts for the fuel they burn and the supplies which they buy for operation and construction. Therefore, it is seldom possible to compare directly any two companies even when the territories which they serve are apparently similar, and the various costs must be divided into suitable units, such as cents per kilowatt-hour, so that different companies may be seen on a comparable basis.

COSTS ANALYZED FROM DIFFERENT POINTS OF VIEW

In this article is submitted a study of the ten major electric utilities of New York State for the year 1926. This particular year was selected because it is the latest year for which the published statistical report (Vol. II) of the New York State Public Service Commission is available. Comparisons are submitted of the various operating costs from different points of view because while in general most costs bear some relation to the kilowatt-hours generated or sold, yet in many cases the dependence is indirect and some other unit is often more nearly constant or at least shows less variation.

Those companies selected were chosen purely on a basis of their size, that is to say the ten companies with the ten largest electrical revenues were taken. Six of the companies are pure electrical companies, numbers 1, 2, 3, 8, 9 and 10 and the other four also have gas departments. All the companies except numbers 2 and 3 center about or are confined to a large metropolitan area. Numbers 4, 5, 6 and 7 also serve wide suburban or rural districts. Companies number 2 and 3 are mainly engaged in the wholesale sales of electricity and in fact the third company does no retail business at all and has less than 200 customers. Table I gives some pertinent physical data and comparative statistics on the various companies which if considered in connection with the various costs later presented will help to explain some of the apparent discrepancies.

TABLE I. PHYSICAL DATA AND COMPARATIVE STATISTICS ON COMPANIES ANALYZED

	1	2	3	4	5	6	7	8	9	10
**Rev. fr. Elec. Sales	11,816	7,793	7,932	6,236	7,210	7,984	4,437	84,116	11,274	33,855
**Total Kw-hr. sold	816,169	868,817	2,314,579	76,870	256,650	536,824	180,342	1,365,235	1,445,772	674,748
% Domestic Rev.	38.4	8.15	0	73.0	36.7	36.4	43.0	*	*	*
% Domestic Sales	36.0	3.26	0	48.0	12.8	8.65	17.1	*	*	*
No.of Customers	162,085	31,575	189	86,705	90,330	78,398	59,638	713,998	119,714	636,953
Steam Capacity	155,000	30,000	-	9,100	72,000	60,000	-	476,000	436,000	415,000
Hydro Capacity	-	37,000	413,000	-	31,000	87,100	-	-	-	-
Steam Use Factor	11.4	0.5	-	0.2	14.7	5.4	-	35.9	38.5	33.9
Hydro Use Factor	-	39.3	66.3	-	63.8	36.2	-	-	-	-
% Elec.Sta.Gen.	16.6	0.1	-	0.3	28.4	4.6	-	61.2	98.5	99.9
% Elec.H.E.Gen.	-	12.9	100.0	-	52.8	44.0	-	-	-	-
% Elec.Rpt.	83.4	87.1	-	99.7	18.8	51.4	100.0	38.8	1.5	0.1
% Total Elec.Sold	87.4	87.0	98.5	81.0	78.5	88.1	84.0	78.5	97.1	81.4

*Data not available
**Figure given is actual figure divided by one thousand

COSTS PER KILOWATT-HOUR IN STEAM PLANTS

Table II presents a comparison of the steam station costs first on a basis of cents per kilowatt-hour generated and second on a basis of dollars per year per kilowatt capacity. Companies number 2 and 4 and 5 appear out of line when compared on this basis but the use factors of the first two are so low that it is apparent that these stations are used only for break down or standby service, hence their unit costs are unimportant. Company number 5 uses its generating station to produce steam for commercial sales and handles the charge by a credit which is here applied to the fuel costs. The last column shows the effect of this credit. Excepting these two

TABLE II. COMPARISON OF STEAM STATION COSTS

	1	2	3	4	5	6	7	8	9	10	5 modified
	Cents per Kw-hr. Generated										
Steam Sta.Supt.& Labor	0.128	2.981	-	1.391	0.218	0.241	-	0.158	0.089	0.146	0.218
Steam Sta.Fuel	0.476	2.036	-	0.737	0.740	0.380	-	0.484	0.349	0.380	0.608
Steam Sta.Water	0.002	0.114	-	0.110	0.016	0.001	-	0.006	0.001	0.004	0.016
Steam Sta.Sup.& Expense	0.010	0.186	-	0.185	0.040	0.077	-	0.016	0.007	0.014	0.040
Steam Sta.Total Dir.	0.616	5.319	-	2.323	1.014	0.699	-	0.663	0.436	0.544	0.882
Steam Sta.Bldg.Maint.	0.010	0.126	-	0.189	0.013	0.003	-	0.013	0.018	0.016	0.013
Steam Maint.Steam Equip.	0.101	1.038	-	0.668	0.100	0.086	-	0.108	0.081	0.054	0.100
Steam Maint.Elec.Equip.	0.003	0.181	-	0.021	0.008	0.003	-	0.007	0.004	0.007	0.008
Steam Maint.Mis.P.P.E.	0.006	0.204	-	0.065	0.002	0.008	-	0.003	0.003	0.002	0.002
Total Maintenance	0.120	1.529	-	0.943	0.123	0.140	-	0.127	0.085	0.079	0.123
Total Steam Expense	0.736	6.858	-	3.166	1.137	0.839	-	0.789	0.511	0.623	1.005
	Dollars per Year per Kw. Cap.										
Steam Sta.Supt.& Labor	1.279	1.302	-	2.130	2.810	1.150	-	3.540	3.310	2.920	2.810
Steam Sta.Fuel	4.780	0.845	-	1.210	9.550	1.800	-	10.990	11.750	7.610	4.670
Steam Sta.Water	0.019	0.047	-	0.181	0.202	0.006	-	0.133	0.019	0.074	0.202
Steam Sta.Sup.& Expense	0.098	0.077	-	0.324	0.512	0.368	-	0.353	0.232	0.288	0.512
Steam Sta.Total Dir.	6.174	2.171	-	3.825	13.074	3.324	-	15.018	14.301	10.892	8.194
Steam Sta.Bldg.Maint.	0.104	0.052	-	0.277	0.173	0.160	-	0.274	0.590	0.328	0.173
Steam Maint.Steam Equip.	1.011	0.429	-	0.635	1.290	0.459	-	2.260	2.650	1.081	1.290
Steam Maint.Elec.Equip.	0.030	0.077	-	0.025	0.101	0.015	-	0.166	0.132	0.144	0.101
Steam Maint.Mis.P.P.E.	0.063	0.084	-	0.130	0.031	0.037	-	0.068	0.078	0.040	0.031
Total Maintenance	1.208	0.633	-	1.278	1.595	0.671	-	2.987	3.841	1.587	1.595
Total Steam Expense	7.383	2.804	-	5.301	14.699	6.995	-	18.009	17.142	12.479	9.778

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During his association with Columbia, Mr. Livingston has done work for Worthington Pump & Machinery Corp. in the hydraulic turbine department, and Northern New York Utilities & Power Corp. as mechanical and electrical engineer, Leeds & Northrup calibrating instruments and E. L. Phillips & Co. as engineer in charge of the operating and statistical department. Mr. Livingston has written many articles for publication in technical magazines on hydraulic power, public utility, cost analysis and allied subjects.

stations the following tabulation shows the range of costs on this basis:

	Cents per Kw-hr. Generated		
	Low	High	Average
Supt. and Labor	0.069	0.241	0.155
Fuel	0.349	0.608	0.478
Water	0.001	0.016	0.008
Supplies and Exp.	0.007	0.077	0.042
Total Direct Cost	0.426	0.942	0.683
Building Maint.	0.010	0.033	0.022
Maint. of Steam Equip.	0.054	0.105	0.080
Maint. of Elec. Equip.	0.003	0.008	0.005
Maint. of Miscel. Equip.	0.002	0.008	0.006
Total Maint.	0.069	0.154	0.113
Total Cost	0.495	1.096	0.796

The second part of Table II compares the costs on the basis of dollars per year per kilowatt capacity. It appears reasonable to expect that certain costs will depend upon the size of the station rather than upon the output and the values presented illustrate that quite clearly. With the exception of company number 8, for example, the variation of station superintendence and labor is only from $2.81 to $1.52 which is a variation of only 142 per cent as distinguished from the 250 per cent variation found on a basis of cents per kilowatt-hour generated and here only one company is omitted from the comparison while in the previous case there were three.

It may be seen that the use factor does not enter into the argument as it did before for, while company number 8 has the second highest use factor and the highest unit cost, number 4 with the lowest use factor has about the same unit cost as number 9 with the highest. In a similar manner, maintenance shows a smaller variation on this basis but even yet there is a great deal. It is believed that maintenance depends upon the two factors —the station capacity and the use factor. A certain sum is needed to keep a station up to satisfactory operating condition whether any electricity is generated or not but as the equipment is used greater maintenance is probably needed. This could be determined only by plotting for any station maintenance costs against output and finding the intersection of the curve drawn through the plotted points with the dollar axis which would determine that fixed portion of the maintenance. This conclusion is borne out by the fact that the station with the lowest use factor has the lowest maintenance cost, while those with high use factors have substantially higher costs.

TABLE III. COMPARISON OF HYDRAULIC STATION COSTS

	1	2	3	4	5	6	7	8	9	10
	Cents per Kw-hr. Generated									
Hydro Supt.& Labor	-	0.027	0.010	-	0.062	0.043	-	-	-	-
Hydro Water	-	-	-	-	0.001	0.001	-	-	-	-
Hydro Sup.& Expense	-	0.004	0.001	-	0.014	0.004	-	-	-	-
Total Direct	-	0.031	0.011	-	0.077	0.048	-	-	-	-
Maint.Bldgs.	-	0.001	0.002	-	0.001	0.002	-	-	-	-
Maint.Res.& Dams	-	0.003	0.001	-	0.002	0.007	-	-	-	-
Maint.H.E.Equip.	-	0.006	0.002	-	0.011	0.007	-	-	-	-
Maint.Miscel.Equip.	-	0.001	0.001	-	-	-	-	-	-	-
Total Maintenance	-	0.011	0.006	-	0.014	0.016	-	-	-	-
Total Hydro	-	0.041	0.016	-	0.091	0.064	-	-	-	-
	Dollars per Year per Kw. Cap.									
Hydro Supt.& Labor	-	$0.829	$0.804	-	$3.430	$1.342	-	-	-	-
Hydro Water	-	-	-	-	0.070	0.029	-	-	-	-
Hydro Sup.& Expense	-	0.123	0.078	-	0.750	0.132	-	-	-	-
Total Direct	-	1.152	0.882	-	4.250	1.503	-	-	-	-
Maint.Bldgs.	-	0.029	0.130	-	0.036	0.059	-	-	-	-
Maint.Res.& Dams	-	0.093	0.038	-	0.082	0.234	-	-	-	-
Maint.H.E.Equip.	-	0.197	0.127	-	0.617	0.338	-	-	-	-
Maint.Miscel.Equip.	-	0.032	0.032	-	0.010	0.008	-	-	-	-
Total Maintenance	-	0.351	0.324	-	0.736	0.519	-	-	-	-
Total Hydro	-	$1.502	$1.012	-	$4.985	$2.022	-	-	-	-

Comparative Costs in Hydraulic Plants

Table III submits similar data for hydraulic plants. As is to be expected, the station with the largest capacity has the smallest unit costs and that with the smallest capacity the largest unit costs. Tabulated herewith are the low, high and mean unit costs.

	Cents per Kw-hr. Generated		
	Low	High	Average
Supt. and Labor	0.010	0.062	0.036
Water	0.001	0.001	0.001
Supplies and Exp.	0.001	0.014	0.007
Total Operation	0.012	0.077	0.044
Building Maint.	0.001	0.002	0.001
Reservoirs and Dams	0.001	0.007	0.004
Hydro Elec. Equip.	0.002	0.011	0.007
Miscel. Equip.	0.001	0.001	0.001
Total Maint.	0.005	0.021	0.013
Total Production	0.017	0.098	0.057

Conclusions drawn from a study of the costs per kilowatt capacity in the previous table can be extended to the hydraulic stations though the paucity of the data forbids any definite conclusions being drawn. A comparison of the average costs of steam and hydraulic power is interesting as the justification of the much higher investment cost and higher use factor in the hydraulic plant is apparent.

Costs of transmission are difficult to analyze without more complete data than the reports of the Public Service Commissions present. The costs depend upon the mileage, the voltage, the design and the location and only partially on the kilowatt-hours transmitted. Table IV presents these costs analyzed on a basis of cents per kilowatt-hour sold but the cost is always relatively small on this basis and the variation is enormous. Companies number 8 and 9, have underground transmission and their substation expenses are enormous, so that their costs are not truly comparable. The true cost of transmission and distribution cannot be obtained without knowing the amount of electricity lost and another point worthy of consideration is that usually the same set of operators work on the high and low-tension boards, hence apportionment of labor charges between transmission and distribution is at best largely arbitrary.

Basis for Analysis of Distribution Costs

Distribution in some cases adds a great deal to the cost of electricity. Table V presents the detailed distribution costs in cents per kilowatt-hour sold, excluding high-tension sales to other public utilities and sales

TABLE IV. ANALYSIS OF TRANSMISSION COSTS

	1	2	3	4	5	6	7	8	9	10
	Cents per Kw-hr. Sold									
Trans.Supt.	0.0114	0.0103	0.0006	-	-	0.0044	0.0067	0.0086	0.0505	0.0069
Sub-Sta.Labor	0.0236	0.0074	0.0013	-	-	0.0117	-	0.0915	0.0333	-
Sub-Sta.Sup.& Exp.	0.0037	0.0009	0.0001	-	-	0.0047	0.0014	0.0171	0.0080	-
Cp.of Trans.Lines	0.0008	0.0058	0.0005	-	0.0004	0.0	0.0003	0.1245	0.2095	0.0077
Total Operation	0.0393	0.0245	0.0035	-	0.0004	0.0307	0.0084	0.2157	0.3342	0.0166
Maint.of Structures	0.0008	0.0005	0.0002	-	-	0.0021	0.0016	0.0160	0.0036	-
Maint.of Sub-Sta.Equip.	0.0061	0.0027	0.0006	-	-	0.0093	0.0048	0.0475	0.0328	-
Maint.of Underg'd.Cond.	0.0003	-	0.0001	-	-	-	-	-	-	0.0006
Maint.of Trans.Lines	0.0034	0.0028	0.0006	-	0.0051	0.0089	-	0.0073	0.0501	0.0406
Maint.of Roads etc.	-	0.0002	-	-	-	-	-	-	-	-
Total Maintenance	0.010(	0.0063	0.0020	-	0.0051	0.0183	0.0062	0.0707	0.0865	0.0412
Total Transmission	0.0495	0.0309	0.004.	-	0.0055	0.0490	0.0146	0.2864	0.4207	0.0578

TABLE V. ANALYSES OF DISTRIBUTION COSTS

	1	2	3	4	5	6	7	8	9	10
	Cents per Kw-hr. Sold (Excl. P.U's. & R.W. Corps.)									
Dist.Supt.	0.0126	0.0031	-	0.0368	0.0626	0.0480	0.0368	0.0366	-	0.0651
Sub-Sta.Exp.	-	0.0044	-	0.1249	0.0665	0.0344	0.0481	-	-	0.0105
Storage Batteries	0.0005	-	-	-	0.0018	-	-	0.0082	-	-
Op.Dist.Lines	0.0026	0.0037	-	0.0434	0.0578	0.0381	0.0089	0.7380	0.3310	0.0428
Meters & Trans.Op.	0.0223	0.0040	-	0.1727	0.0291	0.0305	0.0586	0.0845	0.0500	0.0259
Total Oper.	0.0380	0.0152	-	0.2778	0.2278	0.1610	0.1454	0.2773	0.3810	0.1441
Maint.of Struct.	-	0.0002	-	0.0198	0.0017	0.0008	0.0153	-	-	0.0014
Maint.of Sub-Sta.Equip.	-	0.0011	-	0.0256	0.0215	0.0122	0.0213	-	-	0.0067
Maint.of Stor.Batteries	-	-	-	-	-	-	-	0.0036	-	-
Maint.of Under.Conds.	0.0023	-	-	0.0073	0.0147	0.0024	0.0047	-	-	0.0014
Maint.of Dist.Lines	0.0184	0.0052	-	0.6615	0.0782	0.0550	0.1385	0.0480	0.0407	0.0612
Maint.of Services	0.0036	0.0010	-	0.0961	0.0155	0.0110	0.0096	0.0268	0.0015	0.0214
Maint.of Trans.& Met.	0.0029	0.0037	-	0.0161	0.0208	0.0168	0.0308	0.0047	0.0651	0.0107
Total Maintenance	0.0282	0.0102	-	0.8284	0.1525	0.0982	0.1976	0.0871	0.1073	0.1036
Total Distribution	0.0662	0.0254	-	1.2042	0.3803	0.2592	0.3470	0.4644	0.4883	0.2469
	Dollars per Year Per Customer									
Dist.Supt.	0.640	0.875	-	0.307	1.416	1.240	1.069	0.698	-	0.688
Sub-Sta.Exp.	-	1.231	-	1.042	1.500	0.890	1.297	-	-	0.110
Storage Batteries	0.034	-	-	-	0.039	-	-	0.156	-	-
Op.Dist.Lines	0.133	1.021	-	0.362	1.275	0.726	0.255	4.551	8.805	0.451
Meters & Trans.Op.	1.130	1.115	-	1.440	0.975	1.205	1.612	1.803	1.328	0.274
Total Oper.	1.916	4.242	-	3.151	5.105	4.161	4.333	7.208	10.133	1.523
Maint.of Struct.	-	0.045	-	0.165	0.038	0.021	0.443	-	-	0.015
Maint.of Sub-Sta.Equip.	-	0.205	-	0.322	0.506	0.314	0.618	-	-	0.071
Maint.of Stor.Batteries	-	-	-	-	-	-	-	0.069	-	-
Maint.of Under.Conds.	0.118	-	-	0.361	0.329	0.063	0.137	-	-	0.015
Maint.of Dist.Lines	0.977	1.468	-	5.524	1.755	1.421	3.580	0.935	1.078	0.648
Maint.of Services	0.179	0.368	-	0.800	0.338	0.284	0.249	0.570	0.041	0.226
Maint.of Trans.& Met.	0.148	0.747	-	0.136	0.469	0.424	0.605	0.090	1.725	0.113
Total Maintenance	1.422	2.848	-	6.907	3.436	2.537	5.733	1.664	2.844	1.088
Total Distribution	3.338	7.090	-	10.058	8.541	3.698	10.065	8.873	12.977	3.611

to railroad corporations. In most cases, there is no doubt that there are additional high tension sales but the data as presented do not differentiate between high and low-tension power sales, therefore all other sales except as noted above are used in obtaining the units. As may be seen, the costs vary all the way from 0.025 cent to 1.204 cent which is an enormous spread. It known that company number 2 with the lowest figure has very little distribution, most of its energy being sold at high tension or at least to municipalities so that there is little distribution to run this cost up. Company number 4 is a suburban company with a large overhead network and the maintenance is enormous. Neglecting these two companies, the following range and average is obtained:

	Cents per Kw-hr. Sold (Excl. P.U. etc.)		
	Low	High	Average
Distr. Supt.	0.0126	0.0651	0.0388
Sub-Sta. Exp.	....	0.0665	0.0333
Op. Dist. Lines	0.0026	0.3310	0.1668
Meters and Trans.	0.0223	0.0945	0.0584
Total Operation	0.0375	0.5571	0.2973.
Maint. of Struct.	0.0008	0.0198	0.0103
Maint. of Sub-Sta.	0.0067	0.0256	0.0162
Maint. of Underg'd Conds.	....	0.0147	0.0074
Maint. of Dist. Lines	0.0194	0.1269	0.0732
Maint. of Services	0.0015	0.0298	0.0157
Maint. of Meters and Trans.	0.0029	0.0651	0.0340
Total Maintenance	0.0313	0.2819	0.1568
Total Distribution	0.0688	0.8390	0.4541

Tabulation by dollars per customer per year, as is done in the second part, yields much smaller variation and theoretically is quite sound. It is interesting to

TABLE VI. UTILIZATION COSTS ANALYZED IN CENTS PER KILOWATT-HOUR

	1	2	3	4	5	6	7	8	9	10
	Cents per Kw-hr. Sold for Municipal Light									
Commercial Exp Op.	-	-		-	-	0.1410	0.0153	0.0507		0.2150
Cons.Install.	0.9952	0.1570		1.2195	0.4585	2.1450	0.6675	3.0640	4.6550	4.1900
Munic.St.Lamp Op.	0.4218	0.3670		1.1220	0.4400	0.5265	0.3655	1.2195	0.9945	2.0000
Maint.of Cons.Lts.	-				0.0067		0.0016			
Maint.of Munic.St.Lts.	0.3300	0.5030		0.9117	0.4409	.6375	0.7950	0.7525	0.5985	0.5905
Miscellaneous	0.0360									
Total	1.7945	1.2270		2.3402	1.3852	3.4490	1.8448	5.0867	6.2480	6.9955

TABLE VII. ANALYSES OF COMMERCIAL AND NEW BUSINESS EXPENSES

	1	2	3	4	5	6	7	8	9	10
	Per cent of Oper. Rev.									
Commercial Gen.Labor	1.380	0.175	0.733	1.338	0.880	0.776	0.714	0.455	1.837	1.271
Commercial Books & Contr.	0.974	0.314	-	0.994	0.575	0.505	0.945	3.200	0.964	2.330
Com.Meter Read.& Coll.	0.445	0.355	0.046	0.687	0.905	0.465	0.882	1.263	1.042	2.335
Commercial Sup.& Exp.	0.376	0.102	0.032	1.140	0.877	0.615	0.736	0.696	0.001	0.430
Agents Commission	-	0.053	-							
Total Commercial	3.075	1.003	0.301	4.149	2.789	2.361	3.270	5.614	3.944	6.248
New Business Salaries	0.250	0.038	0.037	0.352	0.176	0.270	0.368	0.300	0.773	0.134
New Business Expense	1.760	1.081	1.135	1.808	1.891	0.821	0.665	2.516	2.935	2.760
Total New Business	2.010	1.120	1.172	1.860	1.767	1.091	1.323	2.815	3.698	2.894
Comm'l.& New Business	4.085	2.123	1.373	5.009	4.556	3.452	4.593	8.429	6.942	9.240
	Dollars per Customer per Year									
Commercial Gen.Labor	$0.201	$0.441	$23.60	$0.954	$0.545	$0.761	$0.531	$0.410	$1.160	$0.677
Commercial Books & Contr.	0.697	0.774	-	0.713	0.460	0.495	0.701	2.880	0.901	1.331
Com.Meter Read.& Coll.	0.320	0.875	18.30	0.494	0.725	0.456	0.656	1.139	0.981	1.341
Commercial Sup.& Exp.	0.269	0.253	8.60	0.817	0.703	0.605	0.543	0.626	0.001	0.232
Agents Commission	-	0.130	-							
Total Commercial	1.487	2.472	119.40	2.977	2.333	2.317	2.430	5.055	3.043	3.372
New Business Salaries	0.179	0.095	14.80	0.252	0.141	0.264	0.267	0.269	0.727	0.071
New Business Expense	1.264	2.681	453.00	1.081	1.276	0.806	0.719	2.260	2.760	1.471
Total New Business	1.443	2.756	468.80	1.333	1.417	1.070	0.986	2.529	3.487	1.542
Comm'l.& New Business	2.930	5.228	586.20	4.310	3.550	3.387	3.416	7.584	6.530	4.914

note that the two companies which were out of line when compared on the previous basis pull into their proper place using this classification. The range and mean values are tabulated below:

	Dollars per Year per Customer		
	Low	High	Average
Distr. Superintendence	$0.307	$1.416	$0.862
Sub-Sta. Expense	0.110	1.500	0.805
Oper. Trans. Lines	0.132	4.551	2.342
Meters and Transf.	0.274	1.803	1.038
Total Operation	$0.823	$9.270	$5.047
Maint. of Structure	$0.015	$0.443	$0.229
Maint. of Sub-Sta. Equip.	0.071	0.506	0.288
Maint. of Underg'd Cond.	0.015	0.329	0.172
Maint. of Dist. Lines	0.048	5.524	2.781
Maint. of Services	0.041	0.800	0.421
Maint. of Meters and Trans.	0.090	1.725	0.907
Total Maintenance	$0.280	$9.327	$4.798
Total Distribution	$1.103	$18.597	$9.845

Utilization is the work which the utility does on the customers' premises and usually consists in the main of municipal street lighting. Table VI presents these costs analyzed in cents per kilowatt-hour sold for municipal street lighting. Obviously those costs which have nothing to do with municipal street lighting will not be comparable with one another but this is the best basis of comparison which was found and was therefore presented in lieu of anything better.

Cost of Carrying on Business

Commercial costs are those costs incident to carrying on the business and consist of those costs of meter reading, bookkeeping, collecting, etc. New business expenses are those costs of promoting and increasing business. Table VII shows there costs on the two most common bases; per cent of operating revenue and dollars per year per customer.

It is seen that the commercial costs vary when compared on any basis but rather less on the later method. Company number 3 is obviously not comparable. Neglecting the metropolitan company number 8, which has an extremely high cost for books and contracts, the following figures are obtained:

	Dollars per Year per Customer		
	Low	High	Average
Commercial Gen. Labor	$0.201	$1.160	$0.681
Commercial Books and Contr.	0.460	1.231	0.845
Comm'l Meter Read and Coll.	0.320	1.241	0.781
Comm'l Supplies and Exp.	0.001	0.817	0.409
Agents' Commissions	....	0.130	0.065
Total Commercial	$0.982	$4.579	$2.781

The new business costs vary considerably no matter how you compare them. The figures below show the variation on both bases:

	Per Cent of Operating Revenue		
New Business Salaries	0.037	0.773	0.405
New Business Expense	0.821	2.925	1.873
Total New Business	0.858	3.698	2.278

	Dollars per Year per Cost		
New Business Salaries	$0.07	$0.73	$0.40
New Business Expense	0.72	2.76	1.74
Total New Business	$0.79	$3.49	$2.11

It appears that, generally speaking, the new business costs are best compared on the per cent of revenue basis.

The general and miscellaneous and other expenses are not here presented because they are practically impossible to find a unit for and also because the policy of the managing company determines the amount of this charge.

They Use Man-Size Coffee Pots in Texas

BETWEEN the intensive cross fire of verbal battle between those water treatment experts who maintain that a boiler is not a chemical retort and feedwater should be treated before entering the boiler and those experts who maintain that treatment should be directed at the boiler water itself, where reactions can take place under operating conditions, are a large number of practical men who are getting good results from both methods and many more who are looking at the question a trifle more broadly and using both methods together.

Of course, the condition of natural waters as influenced largely by local geological conditions has an important bearing on the subject. In parts of West Texas, all natural waters have a high gypsum content which leaves a dense white deposit on boiler tubes and in boiler feed lines.

In some places, it is said facetiously that the mineral content is so high that, under proper weather conditions, water is taken out in blocks or lumps similar to open pit mining. Many plants find it advisable to force the water into the boiler under heavy pressure with a special gun similar to a grease gun used for handling heavy greases.

Conditions may not be as bad as painted, of course, as rumor has a tendency toward exaggeration. There may be more than a grain of truth, however, in the story that in the early days one of the railroads through that section paid a large part of its boiler maintenance charges by periodically removing its boiler tubes, cutting them into six foot lengths, chipping off the metal covering and selling the remaining white cylinders to the ranchers for fence posts. This satisfactorily answered the artistic requirements of the populace in a district far removed from suitable deposits of marble. Of late years, the oil boom has overshadowed everything else causing the demand for decorative fence posts to fall off to a point where the railroads now find it advisable to treat the feedwater chemically in order to reduce tube replacements to a minimum.

This problem of chemical treatment is of some importance although it has been solved in some plants quite successfully by simple means. In one such plant where the water is so thick with gypsum that the engineer screws in eyebolts with which to handle it, he admits under questioning that he has had no scale trouble for ten years.

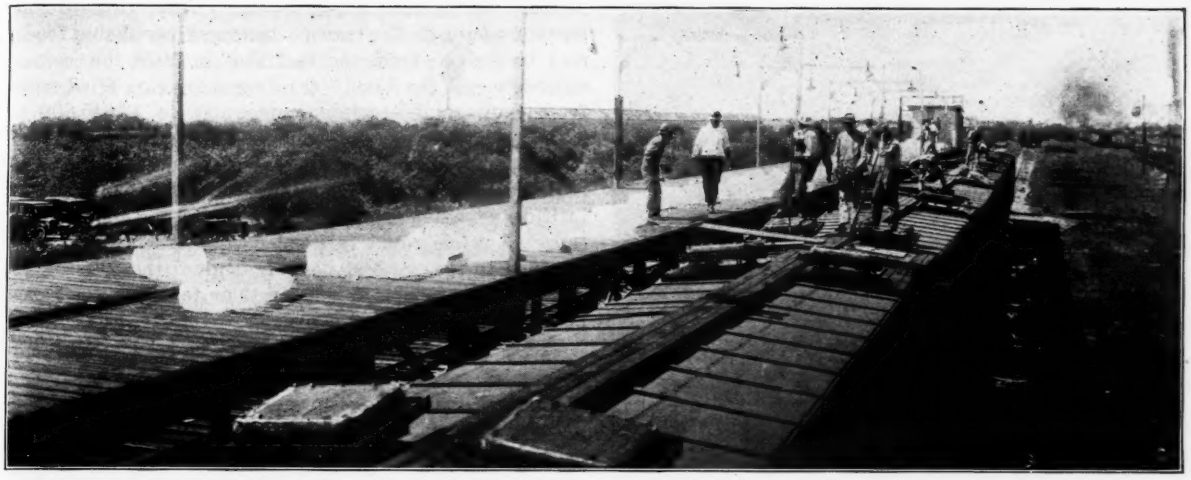
"What! impossible!" you say, reaching down into his open supply tank, picking up a handful and slinging it at the wall where it sticks like a piece of wet putty. Much questioning, some persuasion and a few samples from the reagent bottle of the ever helpful chemist, which, by the way, after taking most of the skin from your throat, is found to be only "pretty fair water for these parts," brings forth the secret.

"Yep! every Monday morning—3 lb. ground fine—10 yr. No scale—clean as a whistle every time she's opened. Discovered it one day batching—noticed the tea kettle all scaled up—coffee pot clean. What kind! Don't reckon it makes any difference to her—coffee's coffee to a boiler—but I like good coffee and it's mighty handy to blow down the glass and have a cup of hot coffee with my dinner. Mostly they don't believe me when they's sober and don't remember when they's not so I don't like to tell about it."

All of which shows that a good engineer will find a way. It does not always meet the approval of experts; in another plant, it might be useless or even dangerous to use but you must admit that it's mighty handy to go over to the water column blowdown and draw off a cup of coffee to go with your midnight sandwich. "Them that has does and them that hasn't, drink water."

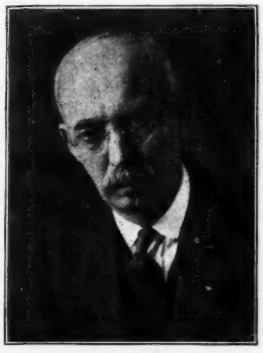
PUMPS SHOULD always be installed over a rigid foundation and fitted with a short direct suction pipe of a size as large or larger than the discharge pipe. The suction lift should never exceed 15 ft. and should be as much lower than this as possible. With warm water, this must be decreased considerable and boiler feed pumps handling hot water should be located so that water flows to them under a considerable head.

Provision should always be made for priming centrifugal pumps by one of several ways: by locating the pump below the suction supply, so that it will fall by gravity; by exhausting the casing with an ejector or vacuum pump, or by use of a footvalve. If the footvalve is tight, the pump will stay primed for long periods but provision should always be made for filling the pump and suction line with water from another source in case the valve leaks or gets plugged.



Refrigeration — Its Relation to the *ELECTRIC INDUSTRY*

By A. J. AUTHENRIETH
Vice-President, Middle West Utilities Co.



A. J. AUTHENRIETH, Vice-President of the Middle West Utilities Co., in charge of ice and refrigeration, made his first connection with the ice and refrigeration industry as plant engineer for the Mattoon (Illinois) Ice and Cold Storage Co. in 1896. In 1898, he was made chief engineer of the municipal light plant of the same city and in 1902 went to the Twin City Ice and Cold Storage Co. at Champaign, Ill. Returning to the Mattoon Heat, Light and Power Co. in 1903 as chief engineer he remained with that company until its merger with the newly formed Central Illinois Public Service Co. in 1910. In the capacity of chief engineer, Mr. Authenrieth was with the latter company until 1917 when he came to Chicago as ice and refrigeration engineer with the Middle West Utilities Co. and in 1925 became vice-president. He has managed the construction or reconstruction of more than 220 ice and cold storage plants in 12 states.

REFRIGERATION, like so many of the other conveniences of modern life, is accepted by the average individual largely as a matter of course. He realizes, dimly, that there is such a process as refrigeration but as to its nature, its application in modern life or the extent of its use, he knows little or nothing. Refrigeration in the home has been enjoyed for so many years that its service is taken for granted and little noticed in the general life at the present time. It receives no more consideration than an occasional passing thought. This unconcern, of course, is not confined merely to refrigeration but to such other important things as his telephone, his electric light, his water supply system, etc. Yet, there are few things in life today, which, if taken away, would be missed more than would refrigeration.

Refrigeration today is one of the most important factors in safeguarding the health of the nation. It safeguards our food supply from the time it is produced on the farm or in the packing house or creamery to the instant it is placed before us on the table. All along the line—in its preparation, during its shipment and in storage awaiting final distribution, refrigeration keeps it in perfect, healthful condition.

Consider the milk supply for a large city. For cities such as New York or Chicago, this comes from an area having a radius of three or four hundred miles. Milk is an exceedingly perishable food; its wholesomeness depends largely in keeping the bacteria count low. With present day distribution methods, from the time the milk is delivered to the railroad cars or the creamery by the farmer, until the bottled product is placed in our home refrigerator by the milkman, it is kept, by means of refrigeration, at a temperature low enough to keep the bacteria count below a safe maximum. Without ice or refrigerating machinery, the distribution of milk in the summertime to millions of people living in cities would be virtually impossible. What is true of the city man's milk supply is likewise true of his meat, his green vegetables and his sea foods.

While refrigeration is of inestimable benefit to the city dweller, it is also of benefit to the farmer; in many cases, more so, for in certain sections of the country the farmer's very existence depends upon the possibility

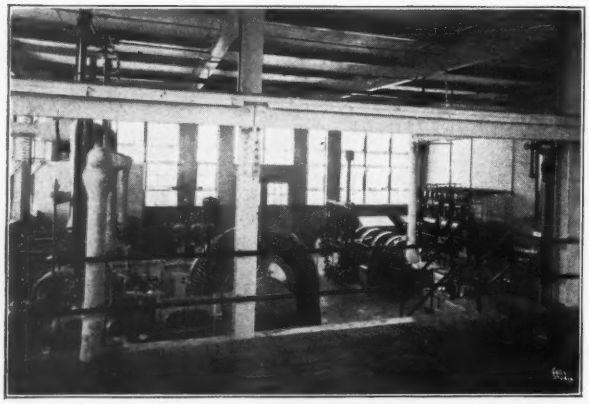


FIG. 1. TYPICAL MODERN ICE PLANT, WITH ELECTRICALLY DRIVEN EQUIPMENT

of refrigeration. Refrigeration acts as a stabilizing factor in the agricultural industry and permits mass production of certain perishable foods which without refrigeration would be economically infeasible. Certain foods are adapted to production in certain localities or climates. Among these are oranges, grapefruits and figs. Other fruits and vegetables can be grown in nearly every locality in this country during suitable season but because of their adaptability to certain combinations of climate and soil, their growth in mass production has been confined to certain definite areas. Localized production of this character is carried out on a scale such that no nearby market could possibly absorb the products, hence without refrigerated transportation which permits their shipment to distant markets, this mass production of fruits and vegetables would not exist.

This aspect of refrigeration is therefore of great economic significance, since it permits the development of remote regions and thus contributes to add to the total wealth of the nation.

Application of Refrigeration

In considering the application of refrigeration in modern life, the subject divides itself into four main divisions.

1. Refrigeration in transportation.
2. Cold storage.
3. Commercial ice manufacture.
4. Domestic and small commercial refrigeration.

That refrigeration has become an exceedingly important factor in the transportation of perishable foods may be judged from the fact that in 1928 the ice required to cool the 1,083,000 refrigerator cars filled with fresh fruits and vegetables amounted to 13,645,800 t. The packing industry alone shipped some 300,000 carloads of meat products under refrigeration, and this increases every year. From the center of this industry in Chicago, shipments go to all parts of the world. Because of refrigerated railroad cars, markets have been widened to the greatest possible degree; those living in small towns are able to supply their tables in the same manner as the large city dweller.

Then there is the transportation of fresh fruits and vegetables, as well as dairy products. Before the advent of refrigerator cars, fresh vegetables could be obtained only when they were in season. Today, the lettuce or celery found on your table throughout the year is brought from Florida or Texas or from the Imperial Valley in California, kept fresh by ice in refrigerator cars. In coming from the Rio Grande Valley to Chicago in the summer, such cars use from 8 to 16 t. of ice. In the past 10 yr., the loading of cars of domestic fruits and fresh vegetables has more than doubled.

The use of refrigeration on shipboard in carrying fruits from the tropics need only be mentioned. The success of the great United Fruit line is based entirely upon the possibility of refrigeration in transit. Most important of the tropical fruits used in this country are bananas. Of these alone, some 64,000,000 bunches a year are shipped to the United States under refrigeration, most of which come from Central and South America. Other tropical fruits are shipped under refrigeration from Hawaii and the West Indies. Even eggs—and this is a fact not generally known—even eggs are shipped from China. Each year hundreds of thousands of eggs are shipped in bulk in cans from China for use in this country by the baking and confectionery trade.

Cold Storage

Closely related to the use of refrigeration in transportation is the keeping of perishable foods in cold storage. The central idea of all cold storage is to provide a reservoir to keep perishable products from the season of production when there may be an oversupply to a season of non-production, when the demand exceeds

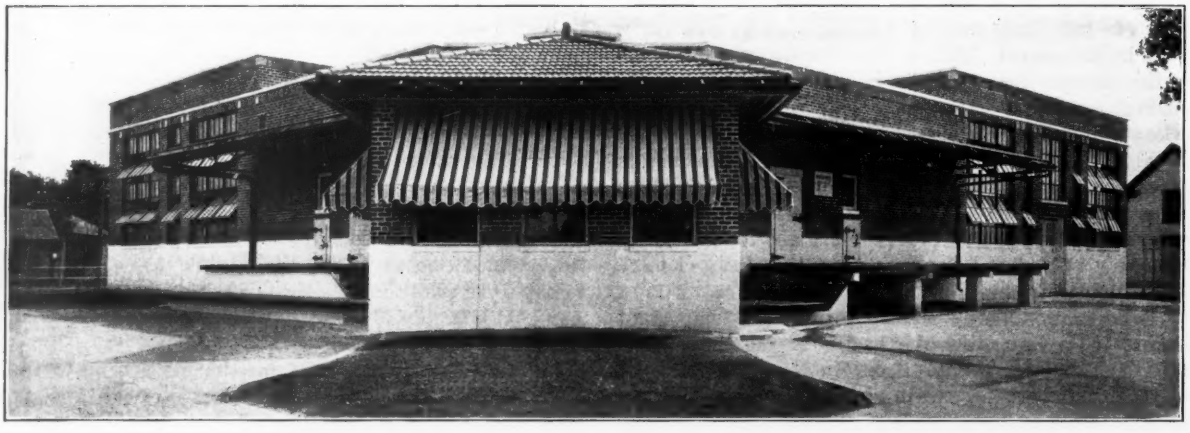


FIG. 2. EXTERIOR OF ICE PLANT SHOWN IN FIG. 1, SHOWING DELIVERY PLATFORMS

the supply. This function is the basis of the greater part of the cold storage industry today. In certain industries, however, such as the packing industry, cold storage is a necessary factor in preparing the commodity produced for transportation and sale.

From the small beginning some 40 yr. ago, the cold storage warehouse business has grown to one of considerable magnitude. At the present time, the total amount of cold storage space in both private and public plants is some 731,377,000 cu. ft., an increase of over 400 per cent in the last 27 yr. Notwithstanding this great increase, the need for more cold storage space continues to grow.

Cold storage is one of the most necessary requirements of the modern city. Without it, we could not live in our accustomed comfort and health. It is illogical to assume, therefore, that a saturation point has been reached in its development. As people become more conscious of its value, more cold storage space will be required. Even today, new cold storage plants are being built in all parts of the country. Here we read of a new 2,000,000-cu. ft. storage in Philadelphia for the Pennsylvania Railroad. Another dispatch announces the completion of a 4,600,000-cu. ft. storage in Houston, Texas. Still another report, gives details of a proposed 2,000,000-cu. ft. plant at San Francisco. The development is general, it is not localized.

Years ago, when cold storage was first beginning to develop, lack of knowledge as to proper methods involved in keeping products in storage brought about a reduction in the quality of the food stored. Naturally, the public being sold these products developed a dislike for cold storage product, particularly when such products were often sold as strictly fresh. This deception was unfortunate and could not long persist. As scientific methods were introduced and more attention was given to the proper time of harvesting products and handling them in transit, the fresh quality of the products was maintained. Also, cold storage products were sold as such. The result was that the confidence of the public was regained and today it has largely lost its old dislike for cold storage products. This will further the future growth of the industry.

According to the figures of the U. S. Dept. of Agriculture, the average cold storage holding time of eggs is 5.91 months; dressed poultry, 2.42 months; butter, 4.43 months; beef, 2.28 months; mutton, 4.45 months; and pork, 0.88 month. The volume and time of peak storage of various commodities from data of the same source is given as follows:

Commodity	Peak Amt. in Stge.	Month of Peak
Apples	9,000,000 barrels	December
Eggs	10,000,000 cases	August
Frozen Eggs	50,000,000 pounds	July
Frozen Poultry ..	124,000,000 pounds	February
Frozen Beef	84,000,000 pounds	January
Frozen Pork	190,000,000 pounds	May
Cured Pork	610,000,000 pounds	May

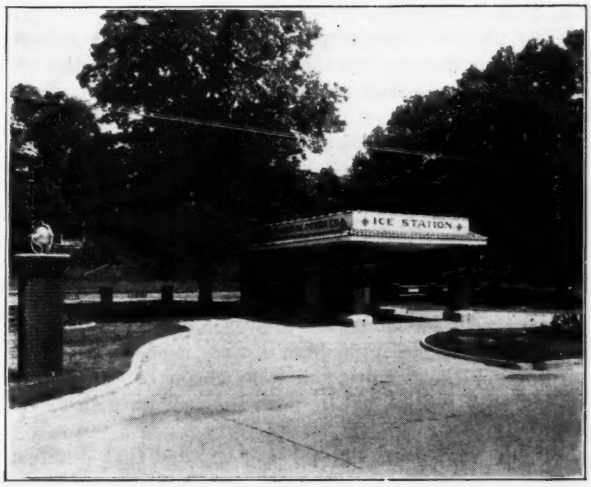


FIG. 4. AN ICE SERVICE STATION AT POPLAR BLUFF, MO.

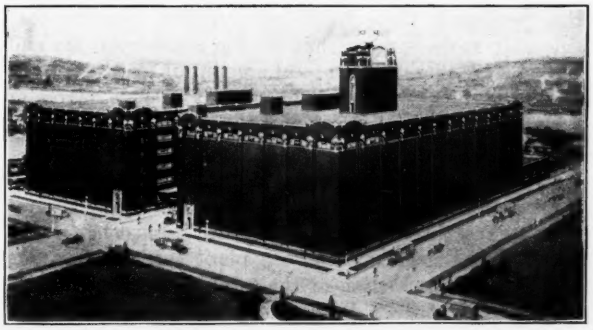


FIG. 3. THE NEW PLANT OF THE U. S. COLD STORAGE CO. AT KANSAS CITY, MO. ICE MAKING CAPACITY, 240 T. DAILY. REFRIGERATING CAPACITY, 1100 T. AND STORAGE CAPACITY, 6,000,000 CU. FT. AVERAGE YEARLY VALUE OF COMMODITIES IN STORAGE ABOUT $3,000,000

While the cold storage industry using mechanical refrigeration has grown by leaps and bounds, the commercial ice industry has not been idle.

The Ice Industry

The Department of Commerce report released early this year shows that in the 3200 plants reporting the 1927 production of ice totaled 40,035,920 and had a value of $183,090,701. The 3200 plants which comprise this report are less than 50 per cent of those listed in the Ice and Refrigeration Blue Book which lists 7300 plants making ice for sale. It has been estimated that the total production of ice, manufactured and harvested, for all purposes in 1928 was approximately 72,000,000 t. Of this, 11,000,000 t. were harvested from lakes and rivers, leaving the total amount manufactured as 61,000,000. Since 13,900,000 t. of this were used for icing cars, the total amount manufactured for commercial and domestic consumption was 58,100,000 t.

There are approximately 7300 ice plants in the United States. Of this number, 32 per cent are steam driven, 59 per cent electrically driven and the remaining 9 per cent oil or gas engine driven. Thus, over half of all the ice plants in this country are electrically driven, a fact of particular interest to the electric utility executive.

This proportion between the number of electrically driven and steam driven ice plants is steadily increasing in favor of the former and in the future we may expect a still further increase. At the present time, very few ice plants are built that are not electrically driven.

This trend toward the use of electric power for the

manufacture of ice is not due to any particular effort on the part of the electric power companies but is a natural trend brought about by the changes in the ice making process—that is, to the advent of fresh water ice.

In the early days of refrigeration, practically all of the ice made was made from distilled water. The distilling removed the air and dissolved minerals from the water and gave a relatively clear ice which was desired to compete with the clear ice of northern lakes. Such plants, naturally, were most suitably driven by steam engines, since the exhaust steam, after being passed through a condenser, produced the distilled water needed for ice making. Boilers were needed regardless of whether the compressors were steam or electrically driven, so it was logical to drive such plants with steam engines.

Later experimenting, however, proved that distilled water was not necessary to make clear ice. It was

FIG. 5. INTERIOR OF ANOTHER ELECTRICALLY OPERATED ICE PLANT

found that by suitably agitating the water while freezing by air agitation, clear ice could be produced from ordinary fresh water. This simplified matters considerably and it eliminated the necessity of boilers and steam condensing apparatus. Since boilers were thus rendered unnecessary, there was no particular advantage in using engines in places where electric power was available, which resulted in an immediate increase in the number of electrically driven ice plants. Today, practically all new plants built make fresh water ice, a fact which has favorably affected the sale of electric power.

Power Requirements for Mechanical Refrigeration

Naturally, the power requirements of an industry with the proportions of the refrigeration industry are considerable, and from this standpoint of direct interest to the electric power companies. Regardless of what branch of the field is considered, whether it be cold storage, ice making or transportation, power is a necessary commodity and since the advent of fresh water ice, this power is most advantageously supplied by the electric utility. Furthermore, the characteristics of the refrigerating load are such as to make it very desirable to the power companies.

On the basis of 731,377,000 cu. ft. of cold storage space in the country and assuming a nominal rate of 60 kw-hr. per 1000 cu. ft. per month, the power used in providing cold storage totals 526,591,440 kw-hr. per month. This, of course, represents both steam and electrically driven plants. Percentage figures are not available but if we assume the same proportion of the total to be electrically driven as is the case in the ice making field, i. e., 59 per cent, then the annual electric power consumption of cold storage plants amounts to 310,688,600 kw-hr., certainly no insignificant figure.

This is for cold storage only; for commercial ice manufacture, considerably more power is required as will be shown.

As previously mentioned, there are about 7300 ice plants in the country, 59 per cent of which are electrically driven. If we assume the same percentage of the total production (61,000,000 t.) for these plants, we find that 36,000,000 t. of ice were produced in electrically driven plants. Using an average figure of 62 kw-hr. per ton of ice, the total electric power used by ice plants in 1928 was 2,232,000,000 kw-hr.

Besides these, there is the domestic and small commercial refrigerator field, which is increasing in extent. While no accurate figures are available, the total of these units in houses and small stores is estimated at around 900,000. Machines of this class may be considered to consume 700 kw-hr. per yr., providing for the total of 900,000 a load of 630,000,000 kw-hr.

Small commercial installations are those used in dairy, ice cream plants. Refrigeration in these plants is used mainly in manufacturing processes and at the present time aggregates more than 80,000 t. Besides there are the refrigerating plants in meat markets and stores, which, though small in themselves, total almost 18,000 installations. With a total of 159,720 t. of refrigeration, these small commercial installations, figured on a 33⅓ per cent load factor, consume 584,575,000 kw-hr. per yr.

Sale of Power for Refrigeration by Electric Utility

It is evident from a consideration of the above estimates that the refrigerating industry as a whole provides a load of considerable magnitude for the electric utilities—one which it will pay the companies to encourage. As already mentioned, regardless of what branch of the field is considered, power is required and this power can be advantageously supplied by the public utility companies.

In recent years, the sale and use of the household type of electric refrigerator has increased tremendously, some 900,000 being in operation. Per unit of refrigeration produced, these small refrigerators consume considerably more current than do the commercial ice and cold storage plants. The total amount of load furnished by these units is considerable and it is of a character which in most cities comes without effort on the part of the power sales force.

While the amount of current used per unit of refrigeration is much greater for the small refrigerator than it is in the commercial ice plant, it must be remembered that the commercial ice plant load is always a much larger proportion of the total load available than the domestic load. Both fields, therefore, are worth cultivating.

As a customer of the electric power company, the refrigerating industry as a whole is very desirable. Not only does it consume a great deal of power, but in

doing so it makes no unusual demands of service. The load is steady throughout the entire 24 hr. of the day and is particularly free from peaks. Furthermore, it is heaviest during the summer months, when the demand on the central station is at its lightest point, thus improving the yearly load factor of the system.

There is another advantage, however, in carrying refrigerating load, and that has to do with power factor. During recent years, the synchronous alternating current motor has come into extensive use in refrigerating plants, for driving the main compressors. The synchronous motor is ideally adapted to this service as its speed is steady and not affected by voltage fluctuations. To the power company, however, the use of the synchronous motor is also desirable because its leading power factor characteristics tend to improve the power factor of the entire system.

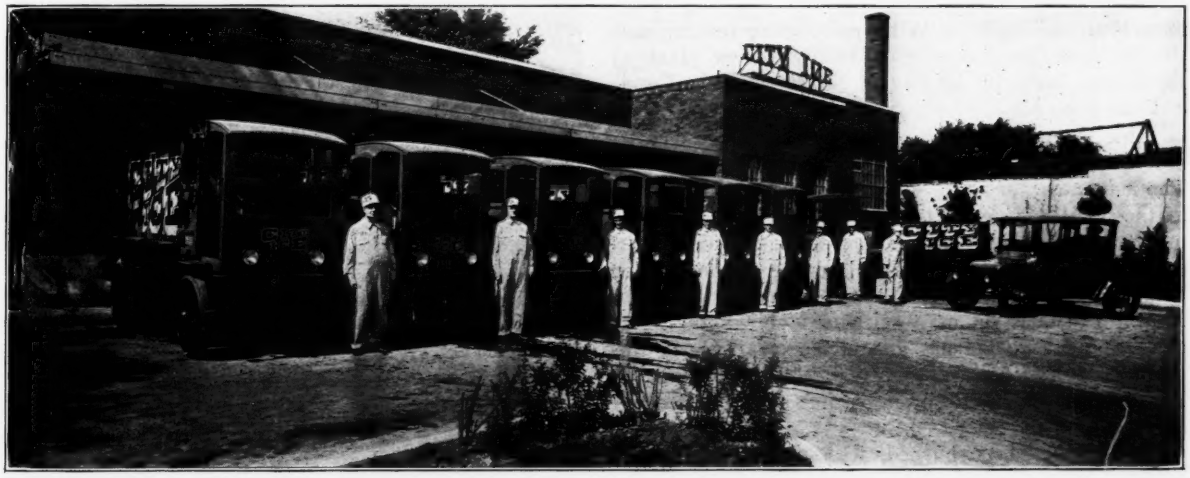


FIG. 6. A FLEET OF ELECTRIC DELIVERY TRUCKS OPERATED BY AN ICE PLANT

Amount of Refrigerating Load Available

From what has been said in the foregoing, it is evident that the refrigerating industry offers an excellent opportunity for load building to the central stations. The commercial ice industry alone, consuming 2,332,000,000 kw-hr. uses more than 3 per cent of the total output of the electric light and power industry. While its growth in the past has been remarkable, the possibilities of the future are even more so. More and more steam driven plants will be converted to the use of electric drive, as the equipment in them approaches the end of its useful life and improved methods of water treatment will make electric drive possible in locations where the condition of the fresh water demanded distillation and steam drive.

Under a previous heading, we estimated the amounts of electric power used annually by the various branches of the industry. Let us combine them and see what the total amounts to:

Cold storage	310,688,000 kw-hr.
Ice making	2,232,000,000 kw-hr.
Small electric refrigeration	630,000,000 kw-hr.
Moderate size commercial installations	584,575,200 kw-hr.
Total	3,757,263,200 kw-hr.

Last year, 1928, the electric energy generated by the electric power companies aggregated 83,100,000,000 kw-hr. The refrigerating industry, therefore, consumed 4.5 per cent of the total. Yet in spite of the enormous power consumption of this major customer of the power industry, with nearly one million installed horsepower, the refrigerating industry fails to find classification separately in the table of electrification of industrial groups in the statistical section of the N. E. L. A. handbook published last year. It would seem well worth while for the utilities to pay increased attention to the refrigerating industry as a source of desirable load.

While the industry has grown steadily during the past 10 or 20 yr., future growth should be even more rapid. The sale of the small electric refrigerator continues in increasing volume. Electrification of existing steam drive ice plants goes on apace.

The sale of large refrigerating machinery was greater in 1928 than in any preceding year while indications point to a 20 per cent increase over this during 1929. The peak, if there is a peak, will be far in the future.

New England Power Association, Worcester, Mass., will push construction this summer on its proposed hydroelectric power development at Fifteen-Mile Falls, on the Connecticut River, vicinity of Monroe, N. H. Work on power dam was begun a few months ago; two such dams will be constructed, each 175 ft. high; the lower dam will create a lake approximately 8 mi. long, while the upper dam, at the head water of the lower reservoir, will form a second lake, approximately 12 mi. in length. The combined capacity of this 20-mi. waterway will total more than 91,000,000,000 gal. Two power houses, to be constructed, will be equipped for a gross output of about 300,000 hp. Energy will be generated at 13,800 v. and stepped-up to 220,000 v. for long distance transmission, the project to include the construction of steel tower lines for connection with present system. A large switching station will be built in the vicinity of the plants. Construction work will be under the direction of the Connecticut River Development Co., an affiliated organization.

Pulverized Lignite Is a Successful Fuel

ALTHOUGH MANY IMPROVEMENTS WILL DOUBTLESS BE MADE IN BURNING THIS FUEL, IT IS BEING USED NOW AS A BOILER FUEL WITH GREAT SUCCESS. BY EDWARD P. PRICE

ON ACCOUNT of the rapid growth of the city of San Antonio, Texas, and the surrounding community, it became necessary for the San Antonio Public Service Co. to consider the erection of a new plant. It was necessary to build on a new site so that sufficient cooling water could be available for condensers. Also it was desirable so that a strictly modern plant could be constructed without being hampered with existing equipment that was obsolete. After considering several locations, it was finally decided to build the new plant on the Comal River in the city of New Braunfels, Texas, a distance of about 30 mi. from San Antonio.

This river is fed entirely by springs and has its source about one-quarter of a mile from the plant site. The maximum variation of the river water temperature at the plant is from 72 to 77 deg. F. Since it is clear and free from objectionable matter, and since no circulating pumps were needed on account of the location being at a fall in the river, the site was thought to be ideal. The question of a suitable fuel was then considered and although gas and oil are available in this district, it was decided to investigate the burning of lignite in powdered form on account of the abundance and cheapness of this fuel.

Lignite had been burned, with varying degrees of success, on grates but little was known about burning it in powdered form. Since the San Antonio Public Service Co. and the St. Paul Gas Light Co. were at that time both properties of the American Light & Traction Co. it was decided to ship about ten car loads of Texas lignite to St. Paul, Minn., to be burned on a test at the Island Station of the St. Paul Gas Light Co. This plant was built to burn a bituminous coal screenings in powdered form and the object of the test was to determine what changes in plant design were necessary for the burning of powdered lignite. Representatives were present from the American Light and Traction Co., Combustion Engineering Corp. and the Texas Power and Light Co.

As a result of these tests, it was decided to design the new plant to burn powdered lignite exclusively; and the Texas Power & Light Co., who also had plans for a new plant at Trinidad,* Texas, decided upon the same fuel. The first installation at the Trinidad plant was to consist of four 2000-hp., 400-lb. Babcock & Wilcox boilers, two 20,000-kw. General Electric turbines and the necessary auxiliary equipment. That at the New Braunfels plant, known as the Comal Power Plant, was to consist of two 2000-hp., 400-lb. Babcock & Wilcox boilers, one 30,000-kw. Westinghouse turbine and the necessary auxiliary equipment. The construction was

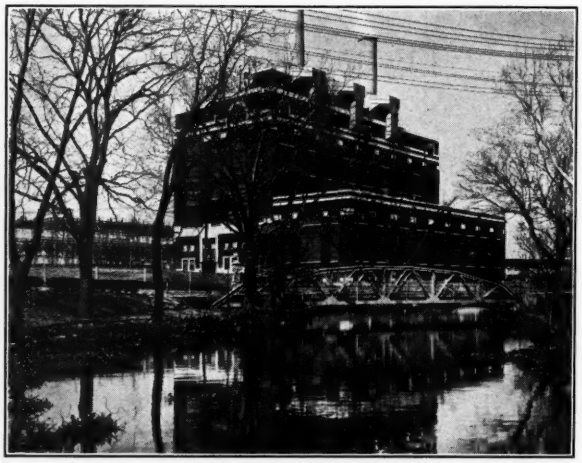


FIG. 1. COMAL STATION STANDS LIKE A FAIRY CASTLE IN ONE OF THE BEAUTY SPOTS OF TEXAS

*See Power Plant Engineering, May 1, 1928, page 520.

EDWARD P. PRICE, *results engineer of the Comal Power Plant of the San Antonio Public Service Co., was born in Weatherford, Texas, in 1895. Following his graduation from the University of Texas in 1921, with the degree of Bachelor of Science in electrical engineering, he went to the University of Illinois as an instructor in the department of electrical engineering, at the same time working for his Master's Degree, which he received in 1923. For a year he was an instructor of electrical engineering in the University of Washington and in the fall of 1924 joined the staff of the San Antonio Public Service Co. in charge of the electric meter department in San Antonio. In the spring of 1926 while the Comal plant was still under construction, he was transferred from the meter department at San Antonio to the position he now holds at New Braunfels.*

started at the Comal Plant in the summer of 1925 and the plant was completed in the fall of 1926. In order that a better idea may be had of this plant in general a brief description of the equipment will follow in which effort will be made to show the interrelation of the various units.

Lignite is brought to the plant in hopper bottom cars which are dumped into the track hopper or put in the yard storage by a steam crane according to demand. An apron conveyor takes the coal from the bottom of this hopper and delivers it to the crushers located just inside of the building and just below the ground level. The coarse coal coming from the first crusher passes to the second crusher and the largest pieces of crushed coal are about nut size. The coal from the crushers goes to a skip hoist through an automatic loader, and is then carried to the top of the building where it is dumped onto a belt conveyor. The belt conveyor is equipped with a magnetic separator for the capture of

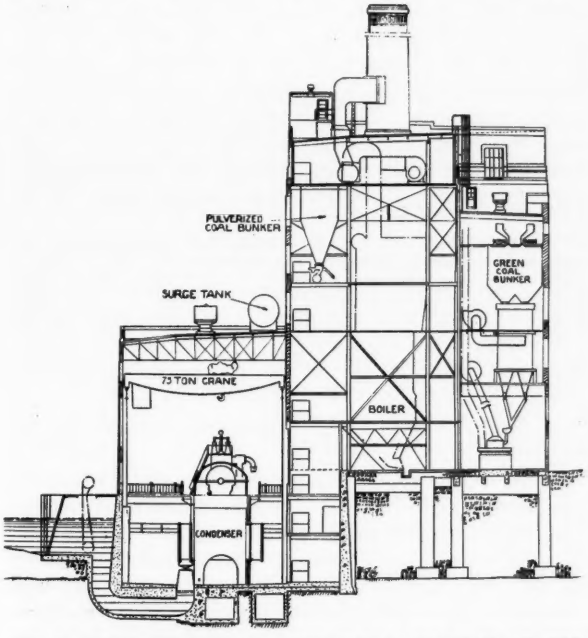


FIG. 2. CROSS SECTION OF THE COMAL STATION OF THE SAN ANTONIO PUBLIC SERVICE CO.

tramp iron, and the coal is unloaded into any one of three raw coal bunkers. The above equipment, with the exception of the bunkers, was furnished by the Link-Belt Co.

Below each raw coal bunker, Fig. 2, is a dryer which consists of a series of steam grids or radiators through which the coal slowly passes on the way to the mill. Air is drawn through the heated coal, and from 4 to 6 per cent of the moisture is removed in this way. Below each dryer is a Raymond mill that has a capacity of about fifteen tons per hour, and the fineness of the coal leaving the mill is shown by the accompanying fineness test.

Furnaces Water Cooled

Powdered coal is floated away from the mills by air and the air and coal are separated in cyclone separators. The air is returned to the mills and the coal passes out of the bottom of the separators into screw conveyors which transfer it to the powdered coal bunkers. Cyclone

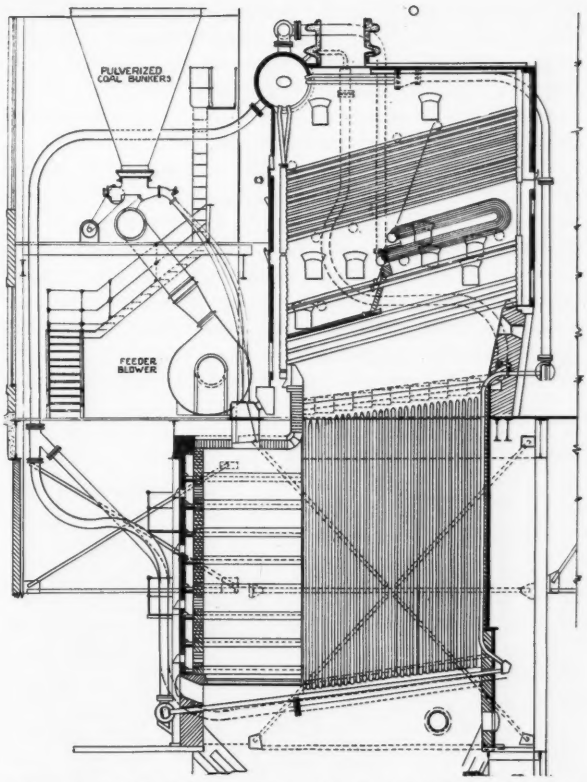


FIG. 3. SIDE WALLS OF THE ORIGINAL FURNACES WERE PARTIALLY COVERED WITH FIN TUBES

separators are also used to take the coal dust from the air that comes from the dryers. This air passes from the separators through air washers to the atmosphere. The mill air system is vented to the dryer cyclone separators, but only leakage air into the system is discharged in this manner.

There is one powdered coal bunker for each boiler, and each bunker has a capacity of about 125 tons. At the bottom of each bunker are twelve feeder screws. These screws draw the powdered coal out of the bunker and it is then mixed with air and blown into the furnace through six-inch pipes that terminate in the top of the furnace arch in fish tail burners. The furnace walls are cooled by fin tubes on the rear and about two thirds of each side. The remaining third of each side and the front are of the hollow Detrick construction, and are cooled by air coming from the preheater. This air enters the furnace through ports in the front wall where it meets the stream of coal coming from the burners above. Its purpose is to support combustion and provide the proper flame contour.

About 70 per cent of the air needed for combustion enters the furnace through the front wall, the remaining 30 per cent is practically all primary air which is blown in with the coal although a small amount, known as

TABLE I. TYPICAL FINENESS TEST OF COAL LEAVING THE PULVERIZERS

Screens	As taken	Oven dried 3 hr.
Retained on 40 mesh	2.15%	1.60%
Retained on 60 mesh	4.99%	4.57%
Retained on 80 mesh	4.92%	4.69%
Retained on 100 mesh	3.24%	2.95%
Retained on 170 mesh	26.50%	19.95%
Retained on 200 mesh	1.39%	1.52%
Past 200 mesh	55.34%	64.75%

tertiary air, enters around the burner casing. The suction of the primary air fan draws air from around the hollow wall of the ash pit and over the furnace arch. The ash pit is protected from the radiant heat of the flames by water screen tubes which mark the boundary between the ash pit and the furnace.

Flames shoot down from the burners to the water screen tubes, turn up along the rear wall of the furnace and enter the first pass of the boiler at the rear of the furnace. The hot gases then pass through the inter deck superheater, the rest of the first pass, the second pass, the third pass and into the air preheater. This air preheater is of the plate type, and was furnished by the Combustion Engineering Corp. The dryers, mills, cyclone separators, screw conveyors, burners and water

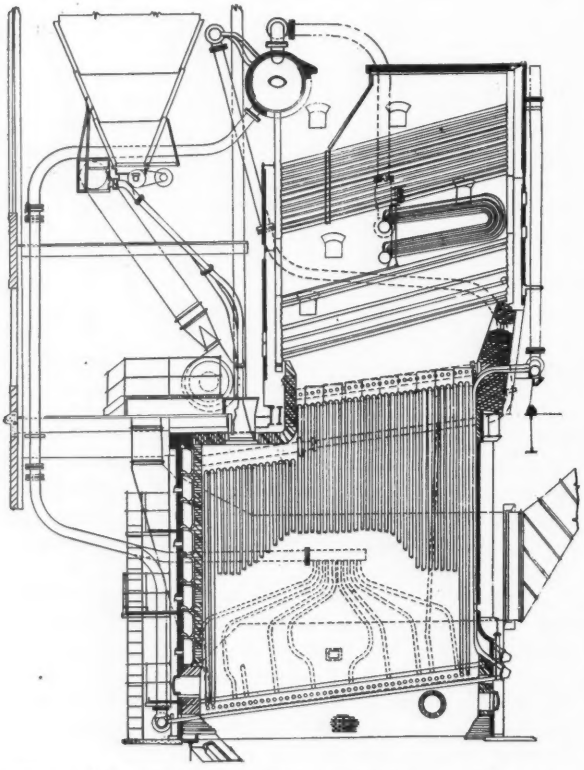


FIG. 4. IN THE NEW FURNACE, SIDE WALLS ARE COMPLETELY WATER COOLED

cooled furnace were also furnished by the Combustion Engineering Corp.

Gases are taken from the air preheater through a Vorticose dust collector by an induced draft fan which discharges them into a stack that rises seventy-five feet above the roof of the plant. The air is forced through the preheater and into the furnace through the ports in the front wall by a forced draft fan. Smoot control equipment is installed to govern the fuel feeder motors, induced draft fans, uptake dampers, air inlet dampers, forced draft fans, primary air dampers and the speed of the boiler feed pumps.

Steam is supplied by these boilers to the turbine at a pressure of 385 lb. per sq. in. gage and 700 deg. F. total temperature. It is exhausted into a surface condenser at an absolute pressure of 1.5 in. of mercury. The water from the hot well of the condenser is carried through four bleeder heaters, and is returned to the boilers at a temperature of about 350 deg. F.

TABLE II. PROXIMATE ANALYSIS OF LIGNITE AS RECEIVED

Moisture	34.80%
Volatil combustible	28.40%
Fixed carbon	27.22%
Ash	9.57%
Sulphur	1.17%
Heat value (B.t.u./lb.)	7000

Coal Has About 30 Per Cent Moisture Leaving the Dryers

Apron conveyors and crushers, that handle the coal as it comes from the track hopper, have given good service; and outside of some minor changes and adjustments at the start, this equipment has given little trouble. An occasional steam shovel tooth or a sledge hammer gives some trouble, but the coal is carefully watched to keep such large pieces of foreign matter from passing into the crushers. The skiphoist and loader have given some trouble on account of being jammed or hung, and several bails have been pulled out of the skiphoist. This trouble has been overcome by providing a stronger bail, and by carefully inspecting and adjusting the entire equipment. The belt conveyor runs over a magnetic separator, and all tramp iron is captured to prevent its going to the mills. There is one operator necessary for the crushers and one operator stays in the

TABLE III. ULTIMATE ANALYSIS OF LIGNITE

Carbon	As Received	Dry Basis	M. & A. Free
Carbon	42.24%	64.85%	76.01%
Hydrogen	6.55%	4.10%	4.80%
Oxygen	39.77%	13.50%	15.84%
Nitrogen	0.70%	1.07%	1.25%
Sulphur	1.17%	1.79%	2.10%
Ash	9.57%	14.69%	0.00%

belt conveyor room. One operator is required in the mill room.

Coal dryers remove only about five per cent of the total moisture in the coal, i. e., the moisture is reduced from about 35 to about 30 per cent. It may appear to be a waste of steam to operate the dryers but, without removing this surface moisture, it has been found that trouble in powdering and handling the powdered coal has developed. It has therefore been found to be highly desirable if not absolutely necessary, to use the dryers. No trouble has been experienced in using the dryers except that the coal will start to burn if it is allowed to remain stationary in the dryers and get too hot. Whenever this occurs, the gates between the raw coal bunker and the dryer are closed and the hot coal is powdered in the usual way. After all hot coal has been removed from the dryer, the gates are again opened and normal operation is resumed.

Operation of the mills in general has been found to be quite satisfactory, and the fineness of the grind has

TABLE IV. CHEMICAL ANALYSIS OF ASH

SiO_2	39.20%
Al_2O_3	24.65%
Fe_2O_3	5.50%
CaO	15.40%
MgO	7.65%
Na_2O	5.19%
K_2O	1.37%
SO_3	1.33%
H_2O	0.55%
Ign. Loss	2.18%
Total	103.02%

been remarkably constant regardless of the wear. In order that a comparison of the effect of lignite with that of other fuels on a Raymond mill may be had, the average life of parts is given in Table V.

The air transport system, including fans, pipes and separators has given little trouble. Some liners in the separators have been replaced after 7000 hr. of operation, mill exhauster blades are replaced about every 1000 hr. of operation and the fan liners about every 2000 hr. The screw conveyors give little trouble, but it is found advisable to clean them occasionally to produce noiseless operation. The screw conveyors, mills and exhauster fans are electrically interlocked so that the mills and fans will stop if the screw conveyors are shut down. This prevents the coal from filling the

TABLE V. LIFE OF PULVERIZER MILL PARTS WITH LIGNITE

Plow points	1500 hr.
Bull ring	5000 hr.
Rollers	5000 hr.

cyclone separators and causing trouble. Also the skip-hoist and crushers are stopped if the belt conveyor ceases to operate. One operator is required on the screw conveyors to attend to them and the boiler fans which are located on the same floor.

Powdered coal bunkers are well covered with heat insulating material to prevent the coal from becoming chilled and causing some of the moisture to condense. After a bunker has been left full of coal for about a week, water will usually begin to run from the feeder screws and the cracks in the lower portion of the bunker, and when the fires are again lighted, in the boiler supplied by this bunker, trouble is experienced in making the feeders deliver enough coal, so burners have to be watched carefully for a few hours to prevent the fires from going out. When a boiler is to be shut down for a few days, the powdered coal bunkers are emptied and cleaned by scraping down the sides, also the feeders are cleaned so that all wet and packed coal is removed. The feeder screws are made of cast iron and begin to show wear on the tops of the threads. This wear was replaced by building up with Stellite and no wear has been noticed since. Some trouble was experienced during early operation with the pipes from the feeders to the burners becoming filled with coal. This was due to insufficient primary air and since proper adjustments have been made no trouble has appeared.

Flame Regulated by Ports in Front Wall

Combustion space under each boiler is 16,800 cu. ft., the boiler heating surface is 18,000 sq. ft., superheater 3697 sq. ft., fin walls 1742 sq. ft., water screen 507 sq. ft. and the preheater 26,568 sq. ft. During preliminary operation, much trouble was caused by bad flame travel. The flames were dark and slow and would go too low in the ash pit, causing much slag to form. Ledges of slag would build out from the rear and front walls and nearly close the ash pit entirely. This slag had to be broken from the walls and removed about once a week, and as high as about 75 t. have been removed from one boiler. In order that some control could be had of flame conditions, it was decided to close some of the front wall ports and restrict others. Also some of the air inlet dampers were completely closed and others were set for a graduated opening. This caused the flame to come out of the ash pit but the contour was not ideal, for at high ratings it beat against the rear wall of the furnace.

It was therefore thought desirable to put all dampers in service and open more ports in the front wall as a compromise between the two extreme conditions. Since the flame conditions have been changed, very little trouble has resulted from slag and a faster hotter flame has been produced by the use of higher primary air pressures. At ratings approaching an evaporation of 200,000 lb. of steam per hour, ash will bake on the lower tubes in the first pass and if not removed by an air lance will seriously restrict the passage. This condition had been anticipated and the boiler tubes had a wide spacing in this area. The second and fourth row of horizontal tubes from the bottom were omitted, but this condition has not been overcome entirely.

In General, Results Have Been Satisfactory

Although some troubles have been experienced in the burning of this new fuel they have been, in general, of minor consequence and the results obtained have been highly satisfactory. In fact, after two years of operation with two boilers and one turbine, it was decided to add the second 30,000-kw. unit and the third boiler. This Walsh & Weidner boiler and the water cooled furnace and air preheater were supplied by Combustion Engineering Corp. The furnace, Fig. 4, is slightly different from the other two in that the two side walls are completely covered by fin tubes instead of being only two thirds covered. The water screen tubes are about twice as numerous as in the two older boilers, and the outside circulating system is radically changed. The feeders, which were also furnished by Combustion Engineering Corp., are different from the feeders on the other two boilers, and their operation is much more reliable and the feed is more constant. This boiler has been in operation for about three months and practically no trouble has been experienced.

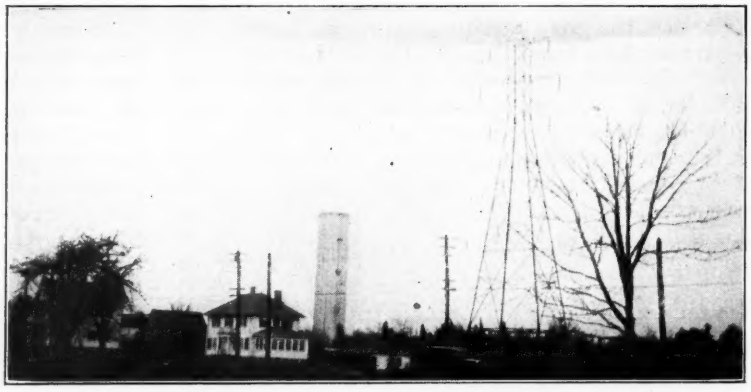
All three boilers are equipped with Smoot Control, and provided with a super master so that each boiler can be operated at a different rating when desired. The ratings are indicated by a Bailey steam flow meter on each boiler, and each meter has a steam flow and air flow pen so that the firemen can use these as a check on their firing conditions. As a further check the two original boilers were equipped with Ranarex CO_2 meters, but the dust in the flue gases has made the operation of these meters unsatisfactory. The third boiler is provided with a Leeds & Northrup CO_2 recorder. This recorder is also troubled by the dust and the moisture in the flue gas, but since it uses less gas than the Ranerex it is hoped that less trouble will be given. As a reliable check on the flue gas, an Orsat apparatus is provided for each boiler, and the firemen have been taught how to use it to check firing conditions and the automatic CO_2 meters.

Although improvements are desirable and many will doubtless be made in the future, it can be said that powdered lignite has been used as a boiler plant fuel with great success; and many industries in the lignite regions will make use of this cheap and abundant fuel.

Economies *and* Applications *of* Aerial Surveys *to* Transmission Line Projects

By

Frederick N. Fowler



ENGINEERS, as the layman thinks of them, are men technically skilled and deeply immersed in facts and figures from which they produce railroads, highways, dams, power houses, bridges, buildings and many other useful projects for mankind's comfort and profit.

Seldom does the layman realize that it is the engineer's well-developed powers of imagination that enable him to absorb the ideas and dreams of others and to develop in his mind's eye those dreams, as well as his own, to a point where he can produce sketches that will enable almost anyone to visualize the project that was the subject of the dream.

Photographs have been for years utilized as a means of translation of ideas and dreams of developments between laymen and engineers. But, until the advent of the airplane and the airplane camera, the pictures produced were only wide-angle perspectives of objects or localities and were in themselves only detailed sketches.

The aerial photograph has been used for many purposes, due to the imaginative powers of the engineer, whereby he is able to look upon either a single picture or an assembly of pictures (frequently termed a mosaic) and see not only the physical features which the camera's eye has recorded but also see constructed (in his mind's eye) the project which he is developing, whether it be a railroad, reservoir, pipe line, transmission line, highway or just a plain, ordinary map for zoning, city planning, assessors' appraisal maps or any other of the many uses that have been successfully made of aerial photographs.

Imagination is a wonderful faculty when controlled and organized, but when uncontrolled sometimes runs wild. The engineer's imagination, generally organized and controlled, does, however, often go on a rampage when he is approached with a new method, radically different from anything he has ever used. He hesitates to depart from the common practices of many years and at once begins to imagine the possible, probable and sometimes improbable errors resulting from the use of the proposed new method.

New methods of doing work slowly supplant old, well-tried methods. The promoter of a new method must be prepared to show savings in time, money or labor; frequently in all three if he is to succeed in having the new method generally adopted.

For over thirty years, practically since the inception of the modern age of power, Mr. Fowler has been intimately connected with the power industry. In 1900, he was assistant engineer and assistant superintendent of construction on the Chicopee River hydroelectric power plant for the Brickam Bend Power Co. From that time to 1907, he was associated, among others, with George N. Merrill & Co., Engineers, United Electric Light Co., New Milford Power Co. and Canaan Power Co. In 1907, he became a partner in the engineering firm of Fowler & Toquet (later known as the General Engineering Co.) engaged in investigations, surveys, designs, reports, specifications and promotion of hydroelectric development in New England, New York and New Jersey. In 1916, he organized a consulting practice as right-of-way engineer specializing in investigations, location, title examinations and purchase of high-tension transmission line right of way. For a number of years, he has made extensive use of aerial surveys in his work and as a pioneer in this work he has been extremely influential in developing aerial photography to its present high standard. He is a member of the American Society of Civil Engineers and maintains his office and organization at 260 Tremont St., Boston.

It is not always easy to prove that new methods are more economical than old methods, particularly so when the user of the new method is so thoroughly convinced of the economies effected, that he adopts the new method and does not trouble to ascertain the amount of the resultant economies. The comparatively new method of making "Area Surveys" by means of aerial photography is of this type, and although now rapidly gaining favor, it has been slow of adoption.

Right-of-way engineers, locating transmission lines for power companies, were among the first to adopt aerial photography. Repeat orders from these engineers, as they had occasion to lay out new lines, tend to prove that they have satisfied themselves that this new method is not only convenient and lessens labor but also saves time and money in locating and acquiring rights of way.

Repeated Use Proves Value of Aerial Surveys

Doubtless, many of them have formulated, in one way or another, opinions of the percentage of actual savings that have been effected. Actual comparisons, however, are seldom available between the use of aerial survey methods and ground survey methods to achieve the same result on the same piece of work, and it is therefore probable that such opinions have generally resulted from mental comparisons between jobs where ground survey methods were used on some and aerial survey methods were used on others.

Many articles have been written on "Aerial Surveys," but the writer has not seen any article containing a practical illustration of a comparison between the two methods, from which could be drawn a definite conclusion as to the amount of the saving effected by using the method of aerial surveys for locating transmission line rights of way. It is for this reason that the following illustration is given.

Actual Comparison of Both Methods Favors the Airplane

A right of way 150 ft. wide and about 30 mi. long was being located and acquired through a rather congested territory. This right of way provided for two lines of steel towers, each line to carry two circuits, vertical suspension 110-kv. power lines. About 4 mi. of this transmission line route was in a section near a large town where it was extremely difficult to obtain a satisfactory location. Three tentative locations had been made by means of ground survey, but all had to be discarded. The location of the right of way on each side of this section had been established and purchased. The usual preliminary ground surveys had been made preparatory to running the center line of a fourth location.

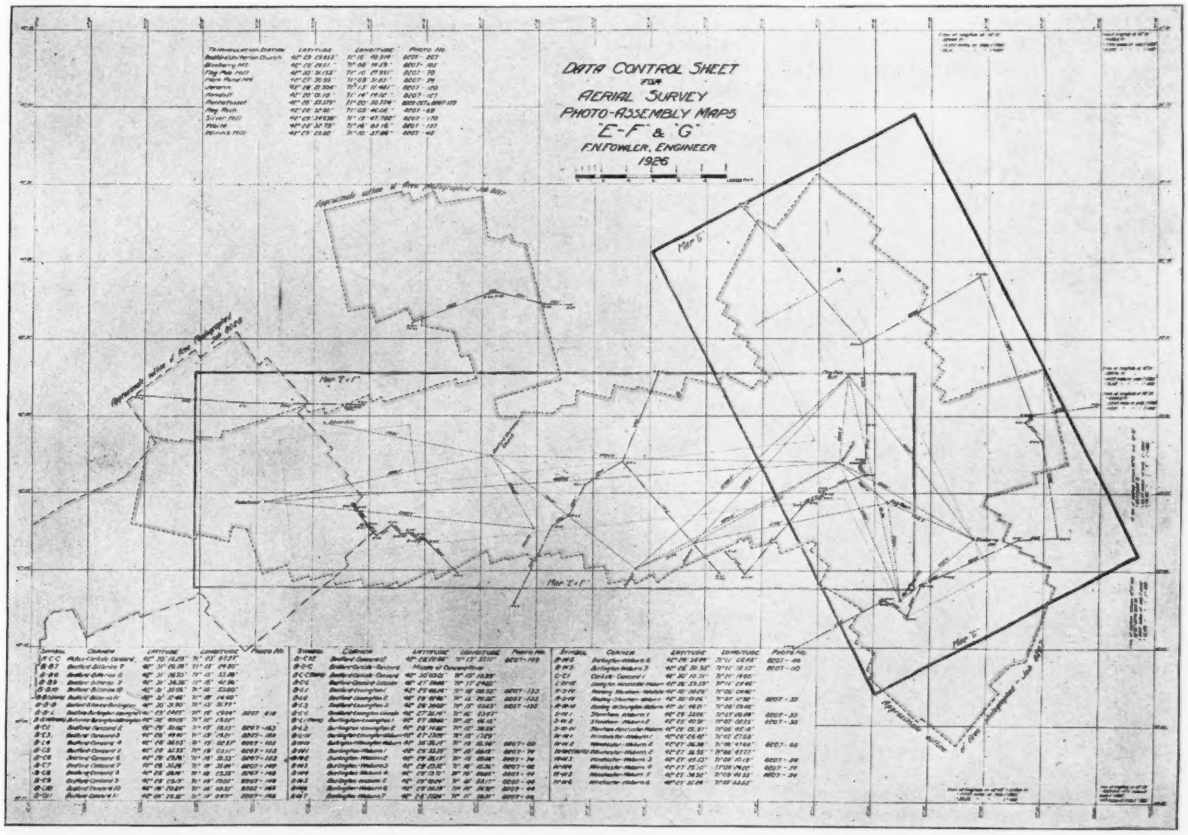


FIG. 1. A MAP USED FOR THE CONTROL OF AN AERIAL SURVEY

While this had been going on, orders were issued for the study of another transmission line project. It was decided to use an aerial survey for the study of this new line, and to include in the aerial survey contract the difficult 4-mi. section of the first mentioned line.

The mosaic of this section was delivered a few days before the survey parties were ready to run the center

line of the fourth location, mentioned above. This mosaic covered about 6 mi. of the right of way, with the 4-mi. section in the center. The center line of the satisfactorily located right of way (about a mile on each end of the 4-mi. section) was superimposed in yellow water color upon the mosaic. In the same manner, the fourth proposed location in this section was also superimposed upon the mosaic.

mosaic. It proved to be, as indicated on the mosaic, satisfactory and 1200 ft. shorter.

If the mosaic had been available from the first, much of the ground survey work would have been unnecessary; considerable time would have been saved and less title work required.

Disregarding the survey and title examination economies and considering only the reduction in cost of the

FIG. 2. ILLUSTRATING CONTROL BY MEASUREMENT BETWEEN EASILY IDENTIFIED POINTS OF CONTACT PRINTS

An inspection of these superimposed lines indicated that the fourth line was satisfactorily located. A further study of the mosaic, however, indicated that by discarding some of the right of way already purchased an equally satisfactory right of way might be located, and the total length of the right of way reduced by 1200 ft. The center line of this last mentioned location was staked on the ground from data taken from the

one tower line, at present constructed on this right of way, approximately five times the cost of the aerial survey was saved by the reduction in the length of the line, as a direct result of the study of the mosaic. When the second line is constructed, the saving will, of course, be doubled.

The foregoing illustration (the only one of its kind that has come to the attention of the writer) clearly

shows that the reconnaissance value of the mosaic is largely responsible for the right of way engineer's ready acceptance of aerial surveys for his particular work.

Every possible location for transmission line rights of way may be laid out on the mosaic, carefully studied, and the most economical route selected. Doubtless, economies are thus effected in right of way property costs, but such economies are, generally speaking, small as compared with the much greater savings resulting from smaller angles, fewer towers and reduced length of conductors, due to the engineer's selection, from the study of the mosaic, of the shortest and most direct, feasible route.

Comparison of the amount and extent of ground survey traverses, where aerial survey methods have not been used and where aerial survey methods have been used to assist in locating transmission line rights of way, indicates that aerial survey methods reduce the ground survey work by about 50 per cent. The saving thus effected will often equal the cost of the aerial survey.

Comparison of the amount of title work required for transmission line rights of way on jobs where aerial surveys were not used and on jobs where they were used indicates that a reduction of approximately 50 per cent of the work of the title examiners has been effected.

Dollars and cents savings in title work varies materially between sparsely settled and thickly settled territories. Seldom will the saving be less than the cost of the aerial survey, and in thickly settled sections the saving effected is sometimes four to five times that cost.

These illustrations of savings, effected by the use of aerial surveys, have been taken from an analysis of transmission line rights of way, located and acquired under the supervision of the writer and in the rather thickly populated sections of Eastern Massachusetts. Since 1924, he has been using aerial surveys for this purpose and it may be of interest to outline briefly the methods he has used in applying them to this work.

Outline of Method Used

A preliminary study is made of such maps as are available, followed by an inspection of the territory by automobile. This preliminary investigation determines the area necessary to be covered by the aerial survey. In congested sections, it is frequently necessary to have five or six strips* of aerial photographs flown but in the less congested territories it is possible to limit the aerial photographic work to a single strip. Generally speaking, however, it is more economical to have at least two overlapping strips photographed.

Control data for the aerial mosaic is furnished in several ways. Where Government Triangulation Stations are available, it is well to make use of them for horizontal control, particularly where a considerable area has been photographed. Town boundary corners are likewise valuable points to be utilized for control. A rather elaborate data control sheet is shown in Fig. 1. Railroad location and highway location maps, when available, furnish very excellent control data. Where it is impossible to obtain the above-mentioned data, it is necessary to measure a distance on the ground between points easily identified on the contact print as has been done in Fig. 2. At least one such distance is necessary for each 5 mi. of each flight strip.

*See Power Plant Engineering, Nov. 15, 1928, page 1188.

The writer believes that a controlled mosaic is well worth its additional expense, as it provides a practically perfect reconnaissance map, showing the physical features in 100 per cent detail. The work need not be held up, however, pending its assembly and delivery. As soon as the aerial survey company has produced the contact prints and received the control data, it can proceed to compute scale ratios from print to print and reduce these ratios to a common ratio, so that all of the prints may be enlarged to the desired scale. These ratio enlargements are merely reproductions of the contact prints at the scale that has been predetermined. The writer generally prefers a scale of 1 in. = 400 ft., as the ratio prints at that scale are of a convenient size from which to make a radial control map and also for use under the stereoscope.

When the contact prints have been delivered, they are pinned down on a drafting board and a preliminary

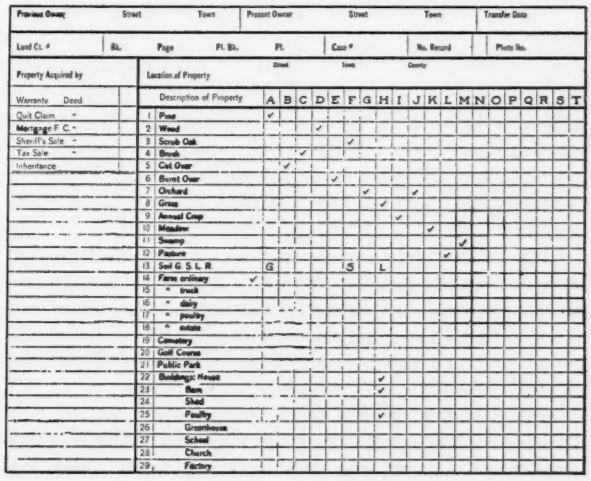


FIG. 3. DATA SHEET USED BY FIELD PARTY TO IDENTIFY VARIOUS PARTS AND OBJECTS VISIBLE ON THE CONTACT PRINTS

study is made of the possible locations of transmission line routes. The best apparent route is selected, marked on the contact prints, and men then go into the field, taking with them these marked contact prints and the data form shown in Fig. 3. They interview the property owners, interest them with the pictures and ask them to point out the boundaries of their properties, as shown on the contact prints by roads, walls, fences, streams, ditches, cleared fields and woodland.

Changed Routes Entail No Loss Other Than a Slight Amount of Labor

Other information, valuable to the locating engineer, the right-of-way buyer and the title searcher, is also obtained from owners or their neighbors and recorded on the contact prints and data sheets. By the time this work is completed, the mosaic has been received and the property lines, which the field party has marked on the contact prints, are drawn on the mosaic, using yellow water color for this purpose. The proposed route or routes are restudied on the mosaic and also under the stereoscope, and the one that appears to be most economical is definitely determined upon and also drawn with yellow water color on the mosaic.

Sometimes, in obtaining the ownership data, it will

be found that the proposed route passes through town, city, county, state or Federal property and that it will therefore be necessary to change the location of the right of way, in which case, a restudy of the mosaic is all that is necessary to relocate the line so as to avoid such obstacles. No field work has been wasted, other than that of marking property ownerships on the contact prints. This in itself constitutes a considerable amount of saving.

Final location of the route having been determined, the property boundaries ascertained and delineated upon the mosaic with yellow water color, a preliminary tracing is taken directly from the mosaic, showing the location and width of the right of way, the property lines with the names of owners, as obtained by the field party, wood roads, streets, water courses, buildings and such other data as may be desirable. The area of the properties affected, measured with a planimeter, is also marked on the tracing.

Prints of this tracing are furnished to the title examiners for their use in the Registry of Deeds. The economies due to the reduction of the Registry work are clearly attributable to the use of these maps. The property lines, roads, streams, buildings and other physical features shown on the preliminary map, traced as above stated directly from the mosaic, will, however, generally be more or less displaced from their true positions.

Where the territory covered by the mosaic is fairly level and thinly populated, it is probable that such displacements will not be serious enough to warrant the expense and time required to correct them by means of radial control; however, where the elevations of various portions of the terrain covered by the mosaic vary considerably and where the territory is thickly settled, the displacement is more serious and warrants the expense necessary to correct the preliminary map by means of radial control.

Radial Control Methods

Eastern Massachusetts is thickly settled and property values are high, hence the next step taken is to correct, by means of radial control, the location of such physical features and property lines as may lie within the area affected by the right of way. The map produced by radial control often shows that certain properties will be affected by the proposed right of way that the tracing (directly from the mosaic) did not disclose and sometimes, in congested territories, it shows the fact that some changes will be necessary in the route itself in order to avoid properties or structures that were so far displaced on the mosaic that they did not appear to be included within the affected area.

In sparsely populated territory, it is possible and practical to run the ground survey of the center line of the proposed route from data taken from the radial control map and if it is in a territory where property is quite inexpensive, even the radial control map may be eliminated and the line run from data taken from the mosaic or from the ratio prints. If, however, the route runs through congested territory where property is expensive, that is, where the right of way will cost in excess of $15,000 per mi., it is, in the opinion of the writer, advisable (before running the center line) to run a traverse with transit and tape around the highways from one end of the line to the other, locating buildings, as well as property lines where they intersect street lines, for a distance of 500 to 1000 ft. on each side of the center line of the proposed right of way.

The road traverse does not need to be a closed traverse, as when platted on the same scale as the radial control map and the tracing of one superimposed upon the other, any errors will be readily detected. If it is found that the ground traverse map and the radial control map do not coincide within the limits of error that are permissible, it is well to rerun such portions of the ground traverse as, from inspection, appear to be in error. This method has been used by the writer and such errors as the dropping of 100 ft. in the measured traverse and the error of reading or recording of an angle by a single degree have been readily located and corrected. The road traverse, thus checked by the radial control map and corrected, provides the data from which the center line location is staked.

Intelligent application of aerial mapping to any work requiring "area surveys" will result in savings in time, money and labor. Methods of application will vary, depending on the type of project for which the survey is made and on the imagination and inventiveness of the engineer in devising ways and means to utilize the aerial maps to the best advantage.

Responsible, well-financed, successful aerial survey companies now have their own well-equipped laboratories and workrooms, airplanes and aerial cameras, skilled mapping pilots, photographers and engineers.

Such companies can and do produce the best aerial maps, and their product, due to constant research and experimental work, is being constantly improved in photographic quality and mapping accuracy.

Prices of such companies are, due to overhead expense, sometimes greater than the prices that newer, smaller and less responsible companies quote but, in the opinion of the writer, it is best to pay the higher first cost for such work and so insure prompt service and delivery of the better and more accurate maps that are produced by companies well equipped and adequately financed.

Department of Commerce announces that, according to data collected at the biennial census of manufactures taken in 1928, the total value of pumps and pumping equipment (including parts and attachments) manufactured in the United States in 1927 was $125,761,928, an increase of 3.6 per cent as compared with $121,344,554 reported for 1925.

The principal items included in the total of $125,761,928 for pumps and pumping equipment made in 1927 are as follows: hand pumps (not including gasoline-filling-station pumps, oil pumps, nor spray pumps), $5,163,209; windmill pumps, $787,662; power pumps (not including gasoline-filling-station pumps, spray pumps, nor pumps for domestic water systems), $46,449,349; spraying outfits (hand and power), $6,390,483; spray pumps (hand and power), $813,553; gasoline-filling-station pumps (hand and power) and tanks, $27,477,749; oil pumps (hand) $6,154,717; domestic water systems, pneumatic (ir cluding domestic-water-system pumps for sale separately), $8,278,052; water softeners, $2,365,089; pumps not specified as to kind or class, $4,186,042; other pumping equipment, $6,529,822; parts and attachments, $9,954,019.

Application of Automatic Synchronizers

FACTORS INVOLVED IN SELECTING AUTOMATIC SYNCHRONIZING DEVICES. PRINCIPLES INVOLVED IN OPERATION. BY C. P. WEST*

CERTAIN TYPES of automatic synchronizers have been in common use for a number of years for controlling oil breakers which connect hydroelectric generators to their load. Recent developments in automatic distribution substations and interconnection of primary transmission systems require new types of automatic synchronizing devices.

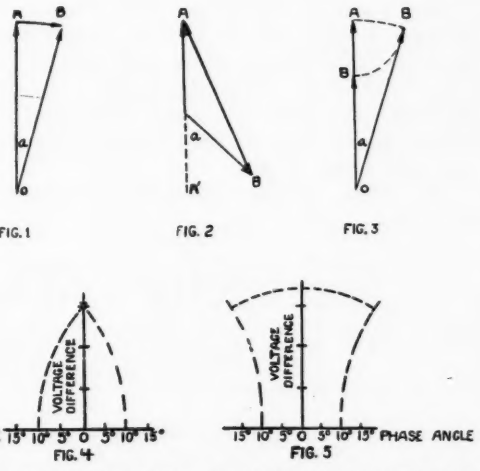
Any switching station, which connects two power systems, can be put under automatic control so that, if the tie is opened during a disturbance, the breakers will be reclosed as soon as the voltage is in phase and the frequencies are nearly equal. Another important application of synchronizing devices is to close several tie breakers located at remote points after a synchronous tie has been established at a station under manual or supervisory control. The success of automatic synchronizing apparatus in these fields and the relatively low cost warrant their use on manually operated generators to assist in synchronizing and in preventing damage or system disturbances if the operator closes the control switch with too great a phase angle between the machine and the bus.

CHARACTERISTICS OF SYNCHRONIZERS

Synchronizing devices of several different types are now being manufactured. These have widely different characteristics and some one type may be selected that will suit the needs of almost any application. The conditions determining the selection of a synchronizer are: first, phase angle; second, voltage difference, and third, frequency difference between the electrical systems to be connected. Fundamentally, a synchronizing device sets the circuit breaker control relays in operation so that the power circuit is closed with the voltages within a predetermined angle and the frequencies so close that hunting will not occur when they are forced to assume the same value. This phase angle and frequency difference is a function of the capacity of synchronous machines on each side of the breaker and the reactance of the circuits.

Any synchronizing device which connects the first tie between two systems or a generator to a system, will have a different frequency applied from each side of the breaker. Thus, if it is set for a given angle, it is certain that this phase relation will be reached. If the device is used to close a loop, or close additional circuits in a network, then no frequency difference will exist and the angle is a function of the loading and electrical constants of the circuit. The phase angle is also an indication of the power flow which will occur when the breaker is closed. Thus the calibration of the synchronizer must not be for an angle so small that, under heavy load, the breaker will not be closed. On the other hand, calibration for too wide an angle will cause closing on overloads and the immediate tripping of the breaker. A relatively simple device can be used for this application, but its characteristics must be such that if a difference in frequency exists on each side of the tie breaker, it will not operate. In some cases, this protection is furnished as a separate relay.

A synchronoscope indicates phase angle and is almost independent of voltage. Automatic synchronizers depend upon voltage as an indication of phase angle and calibration is greatly affected by voltage differences on the system. The synchronizer measures voltage AB (Fig. 1 and Fig. 2) as an indication of the phase angle a. It is apparent that if AO minus BO, shown on Fig. 3, is greater than AB Fig. 1, the two voltages may be in phase, but the synchronizer will be affected as if an angle a existed and will not close the breaker. This



FIGS. 1-5. VECTOR RELATIONS INVOLVED IN OPERATION OF AUTOMATIC SYNCHRONIZING DEVICES

Note: In Figs. 4 and 5, the synchronizing device closes the breaker within limits of the dotted lines.

characteristic is shown graphically in Fig. 4. Thus, if a synchronizer has characteristics as stated, the calibration continually decreases until at a potential difference above 30 volts, the breaker cannot be closed. In a generating station, the voltage differences are under control so this characteristic is not a great handicap; however, in the control of loop or network breakers, a larger difference in the phase angle usually exists, which causes the synchronizer to have too wide calibration at high voltage and too narrow calibration at normal full load condition. The curve shown is typical of one device on the market. Other types have a curve which is not so sensitive to voltage difference.

Some types of synchronizers have voltage compensation and can be made nearly independent of voltage. It is also possible to obtain a widening angle with increase of voltage difference. This characteristic is shown in Fig. 5. The potential difference which exists between two circuits which are to be connected should be carefully considered and specifications should require a synchronizing device to have the correct characteristics.

*Switchboard Engineer, Westinghouse Electric & Mfg. Co.

If two separate electrical systems are to be connected or a generator is being connected to a bus, a different frequency will exist on each side of the tie breaker. The two circuits will then be within a suitable angle for closing the breaker for short intervals and at a greater angle most of the time. If the periods of phase coincidence occur at intervals more than four seconds apart, the speed difference is such that the breaker can be closed at synchronism without undue disturbance to the average system or strain on the windings of a generator. The conditions suitable for closing the breaker may occur at four second intervals or slower. On some types of hydroelectric generators, speed control at no load is very erratic and the suitable breaker closing conditions may occur at various time intervals. This makes hand synchronizing difficult and requires a very accurate automatic synchronizer. Most breakers close the power circuit about 0.4 or 0.5 sec. after the contacts of the synchronizer close. This means that about 0.5 sec. elapses after the circuit conditions have been checked before the two circuits are connected. If the frequency difference is near the limit allowed for synchronizing, it is probable that by the time the breaker contacts close, a large angular difference may again exist between the two circuits. To allow for this condition, it is necessary to limit the operation to almost equal frequencies with accompanying delay in breaker closing or to compensate for these speed changes.

Automatic advance characteristics have been included in the design of one new type of synchronizer. This means that, as the frequency difference between the systems increases, the synchronizer is automatically recalibrated to close its contacts at a greater angle in advance of synchronism. By increasing the angle at which the contacts are set to close, a nearly constant time is provided for the breaker operation, thus ensuring the closing of the breaker contacts in synchronism under all conditions. A synchronizing device with automatic advance and voltage compensation will dependably connect two systems or a machine to its load within 10 deg. of synchronism under any conditions which will be encountered in service.

It is apparent that all synchronizing problems lie in one of two general groups: those where the frequencies are the same (network and loop systems) and those where slightly different frequencies exist on the two sides of the tie breaker. If the application is considered under one of these classes and the phase angles for breaker closing are determined with due regard for voltage difference and frequency difference, an accurate and dependable application for the automatic control of synchronizing breakers can be made. The many advantages of automatic switching are well understood and need not be discussed here. It is now possible to bring under automatic control, any switching problems where the question of synchronizing is involved. The advantage of utilizing automatic synchronizers as an aid to operators in large stations should not be overlooked.

Electricity---What It Is and How It Acts*

PART XXV. FURTHER CONSIDERATIONS OF THE ELECTRIC ARC. ACTION INVOLVED IN SEPARATING TWO CONTACTS. BY A. W. KRAMER

THUS FAR, OUR discussion of the electric arc has been confined almost entirely to the type of arc exemplified by the sustained discharge between two electrodes brought about by the disruption of the insulating gas due to the application of high voltage. While many arcs encountered in electrical work are started in this manner, the large majority of arcs with which the electrical engineer and electrician is concerned are those started when two electrical contacts are separated. This is the type of arc formed at the contacts of a switch or circuit breaker when it is opened. The difference between an arc formed at the contacts of a switch and that produced between separated electrodes by high potential is only in the manner in which the arc is started. Once formed, both types of arcs have the same characteristics.

There is also another type of arc with which almost everybody is familiar but which is not recognized as such and that is the type of arc exemplified by the mercury vapor lamp and the neon tube electric sign. While these arcs present characteristics quite different from the heavy current arc at atmospheric pressure, they are classified as arcs since they are examples of true gaseous conduction. The temperatures attained in this type of arc are considerably lower than those of the heavy current arc.

The neon and the mercury arcs are low pressure arcs, that is, the gas in which the discharge occurs is at a pressure below that of the atmosphere. In the mercury arc, the conduction is between a metal electrode and the surface of a small bright cathode spot on the surface of a pool of mercury in a glass tube exhausted to a pressure of from 0.05 to 1 mm. The mercury is always the cathode. When in operation, the cathode spot dances around continually and is evidently at a high temperature. In principle, however, the mercury arc is not greatly different from the types already described. The same element of doubt exists as to the actual reason for the intense electron emission at the cathode, but it is believed to be due largely to the "pulling out" effect of the positive space charge. So much for the mercury arc.

WHAT OCCURS WHEN TWO CONTACTS ARE SEPARATED

Now, let us consider what occurs when an arc is formed by separating two metallic contacts carrying current. It is common knowledge that when an electric circuit is suddenly interrupted by the opening of a switch or the breaking of a conductor, a bright spark appears at the instant of the break. This spark appears even when the currents and voltages involved are quite small. If a circuit containing only a single dry cell is broken a spark of this type is produced, yet the voltage is only 1½ v. or less.

From our previous study of arc phenomena, we

*All rights reserved.

learned that certain minimum voltages are required to start an arc—several hundred in most instances. Why is it, then, that the opening of a circuit under potentials as low as 1 or 1½ v. gives rise to such brilliant sparks? Despite the low voltages and small currents used, the breaking of these circuits evidently produces high temperatures.

Consider two copper rods placed in contact end to end, as shown in Fig. 1, so that an electric current may flow from one to the other across the joint. Now, by means of a millivoltmeter, suppose we measure the resistance of a few inches of this circuit at two places, as

FIG. 1. TWO CONDUCTORS A, AND B, PLACED END TO END

shown in Fig. 2, first at R and second, across the joint J. Unless the rods have been joined by welding or brazing, it will be found that the resistance at the joint will be slightly higher than that of the copper rod itself. What is the reason for this?

The reason is simple and will be evident at once if we examine the joint carefully by means of a magnifying glass or under a microscope. Looking at it through a magnifying glass, we shall find that the apparently smooth parallel surfaces of the ends of the rod are quite rough and if we apply a high powered microscope, it will be found that the surfaces are not smooth at all and that the rods only make contact at a few places.

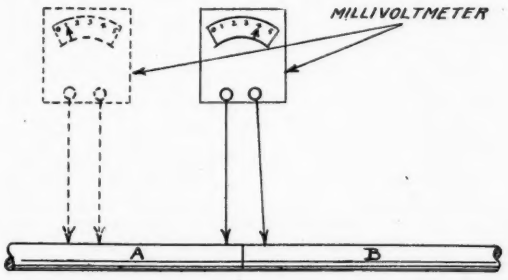


FIG. 2. MEASURING THE VOLTAGE DROP ALONG TWO PORTIONS OF THE JOINED CONDUCTOR, FIRST ALONG A PORTION OF THE SOLID CONDUCTOR AND THEN ACROSS THE JOINT. THE DROP ACROSS THE JOINT IS GREATER BECAUSE OF THE GREATER RESISTANCE

If pressure is applied to the ends of the rods, the resistance of the joint will decrease and observation by means of the microscope will show that due to the compression, many of the points of contact have increased in area and in addition others have been established. It is evident, therefore, that under the latter condition since there are more paths across the joint for the current to travel, the resistance to the total current will be decreased.

As a matter of fact, although we think of the two ends of the rod as being in actual contact, from our study of atomic structure we know that the atoms of the two rods are never in actual contact. Even at the points of contact referred to above, the spacing between two atoms of rods A and B, respectively can never be less than the spacing between the atoms in the rods proper. Thus, at C in Fig. 6, two atoms A′ and B′ of the rods A and B, respectively, are probably as close together as they will ever be, regardless of how much force is used to press the rods together. When more pressure is applied, instead of the atoms A′ and B′ approaching each other more closely, the spaces S_1, S_2, etc., will tend to fill up. Finally, if enough pressure is applied and provided no atoms of gas or oxide are entrapped between the atoms of copper, all the atoms at the ends of the two rods would be as close together as are the atoms in the rods themselves, and the rods would become *one*.

This, of course, is actually what occurs when two rods are welded together. In this case the rods are first heated so that the distance between the atoms is increased, thus permitting them to slide over each other, so to speak, with greater ease.

Having analyzed the action which takes place when two rods are pressed together, it is a simple matter to imagine the sequence of events which obtains when the

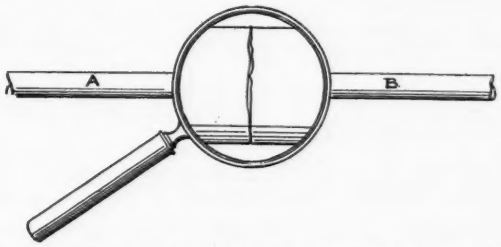


FIG. 3. LOOKING AT THE JOINT THROUGH A MAGNIFYING GLASS

The joint, it will be noted, is not perfectly smooth and contact is made only at certain points.

process is reversed, that is, when two rods are pulled apart to break an electric circuit.

As the pressure is released and as the force on the rods is reversed, there is a gradual separation of the atoms at the boundaries. First, those points which have been under the least stress open up and as the compressive stress is still further decreased other points open up. Finally, (although all of this may occur in the ten thousandth part of a second) there comes a time when the actual contact area of the rods is reduced to a geometric point—the last point of contact.

Resistance of the Last Contact

Now it is evident, that as this occurs—as the contact area of the rods is reduced more and more, the resistance across the joint becomes larger and larger. When the contact area finally reduces to a geometric point, this resistance becomes infinite.

Thus, it is evident that if a gaseous discharge has not started before, all the voltage of the circuit will finally concentrate on this last geometric point. With metal electrodes, this means that there will be an enormous concentration of current and power at the last contact so that an extremely high temperature will be obtained. This temperature, even though only a single volt is acting, comes out far greater than that necessary to melt or even vaporize the metal of the contacts.

Dr. Slepian[1] has investigated this matter and has derived an equation which gives the temperature rise

[1]Temperature of a Contact. Journal of the A. I. E. E., Oct. 1926, p. 930.

of a small contact between large electrodes under an applied voltage. This is

$$T = \frac{E^2}{33.5\ kp}$$

when E is the applied voltage, p the electrical resistivity in ohms per cubic cm., k, the thermal conductivity in calories per sq. cm. per deg. C. per cm., and T the temperature in degrees C.

Applying this equation to the case of a metal having values $p = 10^{-5}$ and $k = 1.0$, for a difference of potential of one volt we find that the temperature produced at the last contact is

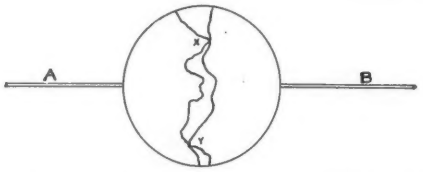


FIG. 4. UNDER A HIGH POWERED MICROSCOPE, THE JOINT WOULD LOOK SOMETHING LIKE THIS

Here the roughness of the surfaces is shown even more clearly. In this section, contact is made only at the points X and Y.

$$T = \frac{1}{33.5 \times 1.0 \times 10^{-5}} = 3000 \text{ deg. C.}$$

If, instead of one volt, the potential acting on the circuit is 10 v., the temperature comes out theoretically at least, 300,000 deg. and with 100 v., 30,000,000 deg.

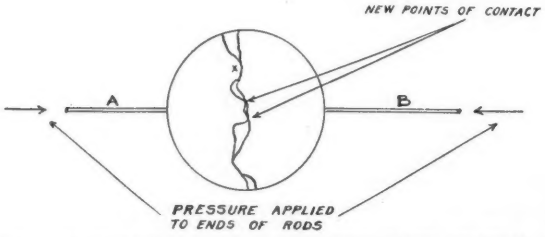


FIG. 5. A MICROSCOPIC VIEW OF THE SAME SECTION AS THAT SHOWN IN FIG. 4 WHEN PRESSURE IS APPLIED TO THE ENDS OF THE RODS

Upon the application of pressure, the points of contact X and Y are broken down and the area of contact increased. This allows other portions of the rods to approach each other more closely, thus establishing new points of contact. Thus the application of pressure decreases the resistance of the joint.

Of course such temperatures as the last two are never reached and perhaps neither is the first, but this equation shows that temperatures sufficiently high to vaporize the metal of which the contacts are made may be obtained even with very small voltages. With such high temperatures also, there should be sufficient thermionic emission to start ionization of the gases between the contacts, thus establishing an arc.

Effect of Gas on the Arc

Although an arc can be started in this manner, the continuance of the arc after the contacts have separated must be due to some process of ionization of the gases between the arc terminals. This is borne out by certain experiments by Sorensen and Mendenhall[2] on breaking electric circuits in vacuum.

If the arc is actually due to ionization of gases between the terminals, it is evident that in a perfect vacuum an arc could not be maintained. Of course, by introducing a heated cathode into a vacuum as is done in a vacuum tube, a space current will flow but this is not an arc in the usual sense. A number of investigators, before Sorensen and Mendenhall had experimented with switching in vacuum, without very definite results. Even in high vacuum (0.001 mm.) they found severe burning of the contacts and luminous flashes, at the instant of opening with currents of one and two amperes.

The failure of these experiments in suppressing the formation of an arc was due, evidently, to the fact that the degree of vacuums used[3] was insufficient.

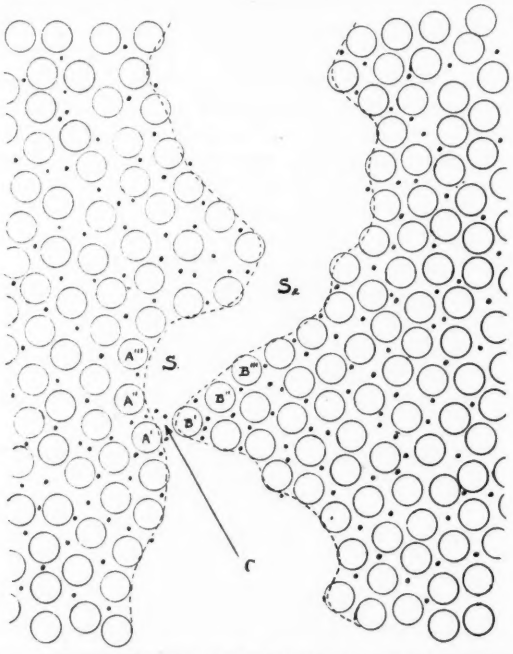


FIG. 6. IF WE COULD ACTUALLY SEE ATOMS, THIS IS HOW THE JOINT WOULD APPEAR

The point C is what we call a point of contact, but as will be noted there is no actual contact of the atoms A′ and B′. These two atoms are probably as close as they ever will be, the distance between them being the same as the distance between the atoms of the metal. If pressure is applied, the atoms A″, A‴ and B″, B‴ will undergo displacement, causing the space S, to diminish.

Sorensen not only used the best obtainable exhausting equipment, but all the electrodes used were carefully denuded of all gases. The vacuums used were as high as 10^{-6} mm.

With such vacuums, Sorensen found that even when the switch opened 926 amp. at 41,500 v. there was no pitting or burning of the contacts and no appreciable arc. When the contacts separated, there was a visible arc, but this persisted for only a very small fraction of a second. This flash no doubt was due to the heating of the last contact point and the consequent thermionic emission, but because of the absence of gas in the vicinity this thermionic emission did not produce ionization.

From these experiments, it is very evident that arc is dependent upon the presence of gas, and that the arc is largely an ionization phenomenon, in which the electron plays a most active part.

Before leaving this subject of the electric arc, it may

[2]Vacuum Switching Experiments. A. I. E. E. Transactions, 1926, page 1102.

[3]As high as 0.001 mm.

be of interest to investigate briefly, why an arc can be maintained more easily in certain gases than in others. This is due to the difference in ionization potentials of different gases.

Ionization has been described as the process of removing an electron from a neutral atom against the attractive power of the nucleus of the atom. Now, it may be recalled from our consideration of the structure of atoms of various chemical elements, that certain of the electrons in the outer orbits were more easily removed than others; in fact, it was the varying tendency of atoms to lose or acquire electrons that was responsible for the ability of one chemical element to combine with another. Certain elements were found to have atoms in which the electrons were so disposed as to form exceedingly stable systems—these were the inert gases, helium, neon, argon, krypton, etc. There were other elements, such as sodium and lithium which had a single electron in one of the outer orbits which was easily removed. Thus the atom of helium with two electrons in its orbit is stable and neither of the electrons is easily removed, but the atom of lithium with three electrons, one in the outer orbit, is unstable with its third electron and for this reason is willing to give up this third electron.

An atom of this latter type, it must be obvious, can be ionized more easily than can one of the former type and this is borne out by experiment. The ionization potential of helium, for instance, is about 25 volts, while that of lithium is 5.1 volts. In other words, a free electron must fall through 25 volts before it acquires sufficient velocity to ionize a neutral atom of helium but in the case of lithium, it need fall through only 5.1 v. Thus certain gases have lower ionizing potential than others and therefore are better suited to maintain the electric arc.

It Pays to Build Beautiful Power Plants

THEY POSSESS GREAT ADVERTISING AND GOOD WILL VALUE, IMPROVE MORALE OF OPERATING FORCE AND LEAD TO HIGHER EFFICIENCY. BY WILLIAM H. EVANS*

MANY THINGS impress the visitor to the modern generating plant: the tremendous size of the generating units, the relatively few men needed to operate the plant, the increased efficiency in operation due to fuel and labor economies and so on. These necessarily make a greater appeal to the visitor if he happens to be an engineer. On the other hand, the big boilers, condensers and turbine generators are just as mysterious to the non-technical visitor as electric power itself. He knows that coal, water and air in some strange way are transformed into energy that lights his home and runs the motor-driven machinery in his mill but just how all this is accomplished is vague and indistinct. Yet he cannot help being impressed by what he sees, even though he does not understand how things function.

There are, however, certain definite things that are stamped in his mind, which, while plain to the engineering visitor, are not particularly noted, because his engineering mind is on other matters of more material interest to him. And among the things which impress the non-technical visitor and which makes a peculiar appeal to him are the architectural beauties of these buildings of brick and stone and mortar, the cleanliness and neatness indoors and out, the landscaping and general physical appearances of the generating, transmission and distribution stations.

VALUE OF ATTRACTIVE SURROUNDINGS

The psychological effect of this on the personnel also plays a prominent part. The operator, the oiler, in fact, every employe who works in a building, is affected by the surroundings. If the building is beautiful in its lines or stands out from others because of its architectural grace, the employe takes greater pride in his work than if the equipment is housed in a building erected merely to protect the machinery. If the grounds have been landscaped, the men who work on the outside see to it that everything is kept neat and clean. Aside from the incentive to do a good job, those men who work where they are surrounded by beautiful things are unconsciously affected and influenced by them and put greater effort and pride into their work.

It may cost a bit more for graceful buildings, a different kind of brick or stone trim may add to the cost and more ground may be bought than is actually needed for operation, yet the net result in maintaining or cementing public relations and good will and in instilling pride in the employe more than offsets the additional expense.

Years ago, generating stations and substations were necessarily smaller, because the business did not justify the construction of larger plants. In many cases, the buildings housing the equipment were just buildings. They were designed and built for service and the thing that counted was not the building itself but what it contained. They were built to perform a certain work and that was all that was required of them. In other words, they were just brick and stone and mortar. If their lines were architecturally good, that was a secondary consideration. The public did not see much of them and, if it did, they made no more appeal than a warehouse or some other useful but plain building. A few public utility companies put beauty into all their buildings but they were the exception rather than the rule.

If the public did get into these old-time plants, it was not particularly impressed. The machinery and equipment were as efficient as was possible in those days but the interior, so far as architectural grace and beauty were concerned, was just as unimpressive as was the exterior. Beauty of either exterior or interior was not thought of, as it contributed nothing to the efficiency of the plant, which was the sole consideration. The grounds surrounding the building were more or less unkempt and the yards were cluttered up with material and construction equipment. There were no grass plots or shrubbery and if there was any grass at all, it was

*Public Relations Department, The Philadelphia Electric Co.

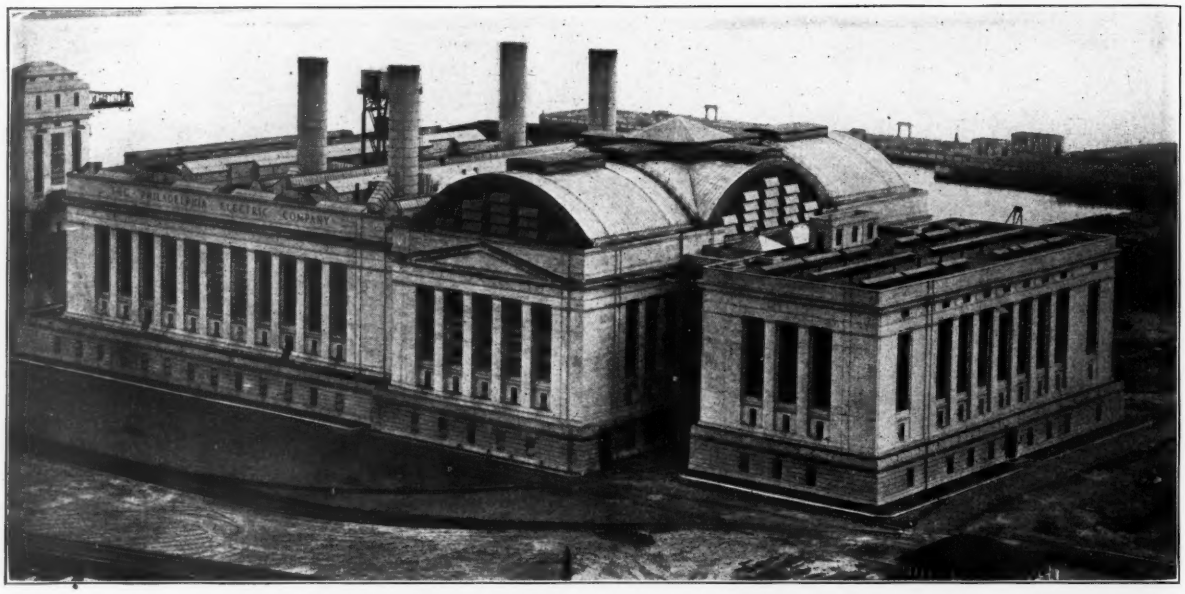


FIG. 1. AIRPLANE VIEW OF RICHMOND STATION SHOWING LANDSCAPING

mostly weeds and uncut grass. This picture may be a bit overdrawn but it is more or less typical of the old days.

Beauty and Efficiency Go Hand in Hand

Contrast this with present day methods in generating stations and substations. Architecture has come into its own in the great majority of public utility buildings. Architecturally they will compare with most of the splendid office buildings to be found in any progressive American city. While everything that goes into the building is designed to perform certain specific work in the most efficient and modern way, into the stone and brick and mortar have gone graceful lines and beauty is just as much a part of the modern plant as efficiency of operation.

As an illustration, when the Richmond generating plant of The Philadelphia Electric Co. was first under consideration, it was known that it would be built on the Delaware River near the bridge over which the Pennsylvania Railroad carries its hundreds of thousands of passengers to and from Atlantic City. Up and down the river would ply passenger boats and other river craft. Conceived as it was then, to be the largest steam generating plant in this country, it was known that these hundreds of thousands of men and women would see it. In order to set off the huge mass of building to the best advantage, it was built so that it appears to stand on a terrace well above the river. A lawn stretches from the building to the water's edge.

At night it is flood-lighted, so that those on the fast moving trains, as well as passengers on the river craft, have a thing of beauty to gaze upon, for the lighting brings out the fine classic lines of the building and reveals details not seen in the day time. Inside, the lofty turbine hall, with its high vaulted roof, is almost like a cathedral in its beauty. Even the matter of proper lighting and paint has added to the beauty of the room without detracting in the slightest way from the use to which any turbine hall is put. Inside and out there is an atmosphere of good housekeeping of which any housewife would be proud. The big yard is kept spick and span and there are grass plots and strips of closely clipped turf in keeping with the beauty of the building.

Delaware Station was built alongside Penn Treaty Park, where William Penn signed a treaty with the Indians. The park is small but is gay with flowers; there are grass plots and a monument marks the place where the tree once flourished under which Penn and

FIG. 2. AT NIGHT, FLOODLIGHTS DISPLAY TO GREAT ADVANTAGE THE CLASSIC LINES AND DETAILS OF RICHMOND STATION

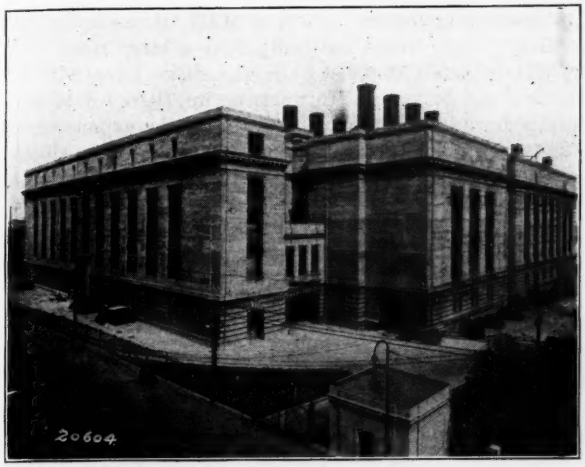


FIG. 3. DELAWARE STATION IS NOT AT ALL OUT OF PLACE FACING PENN TREATY PARK, SHOWN IN RIGHT FOREGROUND

the friendly Indians signed their compact of peace more than 240 yr. ago. This station is also architecturally a splendid building. The yard surrounding it and adjoining the park is kept neat so that no jarring scene greets the visitor who comes to view the historic park.

Same Principles Are Applied in Substations

One of the most modern of the numerous substations of The Philadelphia Electric Co. is Wister. Directly across from it is the Germantown Hospital and all around it are fine old houses characteristic of one of the most beautiful residential sections of Philadelphia. As this substation was to be built in the center of a highly restricted neighborhood, everything was done to fit the station into the surroundings. As a result, old trees still stand in front of the station and all around it are well kept grass plots and groups of shrubbery, while the station itself is in architectural keeping with its neighbors.

Four times a year, the four superintendents of the main generating stations visit the various substations for a survey of the exterior and interior, noting the

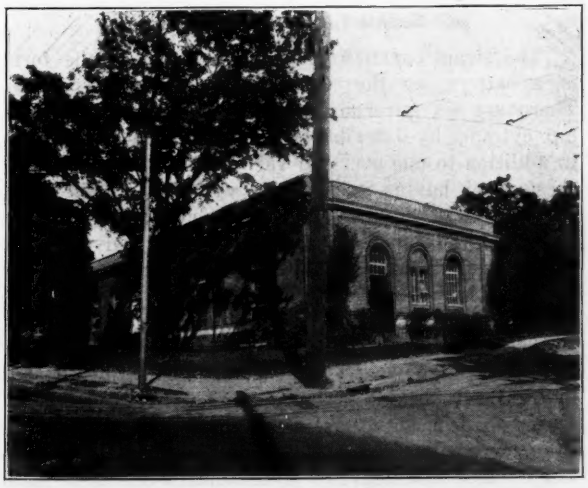


FIG. 4. WISTER SUBSTATION WAS DESIGNED TO FIT UNOBTRUSIVELY INTO THE NEIGHBORHOOD IT SERVES

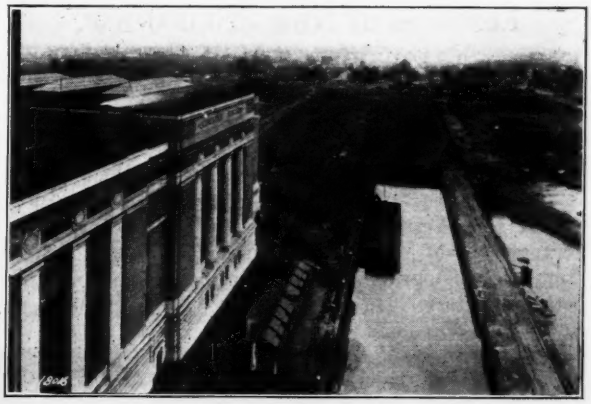


FIG. 5. PARTIAL VIEW OF CHESTER STATION, SHOWING HOW NEAT AND CLEAN THE COAL PILE IS KEPT

condition of the equipment, the general appearance and neatness and other points of good housekeeping. At the end of the year, the station scoring the greatest number of possible points is awarded a certificate and members of the staff each receive a money award. The certificate (which is later hung in the substation) and the awards are presented at a meeting of the employes. This housekeeping contest was started 7 yr. ago and has done much to instill and promote pride in the various substations among the operators.

In the congested sections of the city, whether in business or residential centers, the substations of the company add to and never detract from the surroundings. Care has been taken that they are as fine architecturally as they are splendid in station efficiency; and where substations are built in the suburbs, everything is done to see that the stations architecturally meet with the approval of the most critical eye. Where landscaping is possible, this is also done.

The three modern generating stations, Richmond, Delaware and Chester, are architecturally patterned after the Graeco-Roman classical buildings as shown in the English Renaissance after the Napoleonic wars. John T. Windrim, director and architect of the company, who has designed all the Bell Telephone Co. buildings in Pennsylvania and who is also architect of Girard College, has designed all the generating and substation buildings of the company and into each and every one he has embodied much architectural grace, so that they are buildings of beauty as well as structures of utilitarian efficiency.

Pennsylvania Railroad Co., Broad Street Station, Philadelphia, Pa., has awarded a general building contract to the United Engineers & Constructors, Inc., 112 North Broad St., for a new steam power plant and electric substation at 32nd and Market Sts. Work will proceed at an early date. Plans were drawn by Graham, Anderson, Probst & White, 80 East Jackson Boulevard, Chicago, Ill., architects and engineers.

New orders for 1466 steel boilers were placed in March as reported to the Department of Commerce by 81 manufacturers, comprising most of the leading firms in the industry, as compared with 1028 boilers in February and 1462 in March, 1928.

Features of New 320,000-Kw. Extension at Hell Gate

(Continued from page 613)

coolers which are of the extended surface type. The combined capacity of the two blowers on this machine is 264,500 c.f.m.

On the Westinghouse unit, an entirely different arrangement of ventilation is used. As may be noted from the photograph, a single casing is built around both generators. Three vertical propeller type blowers

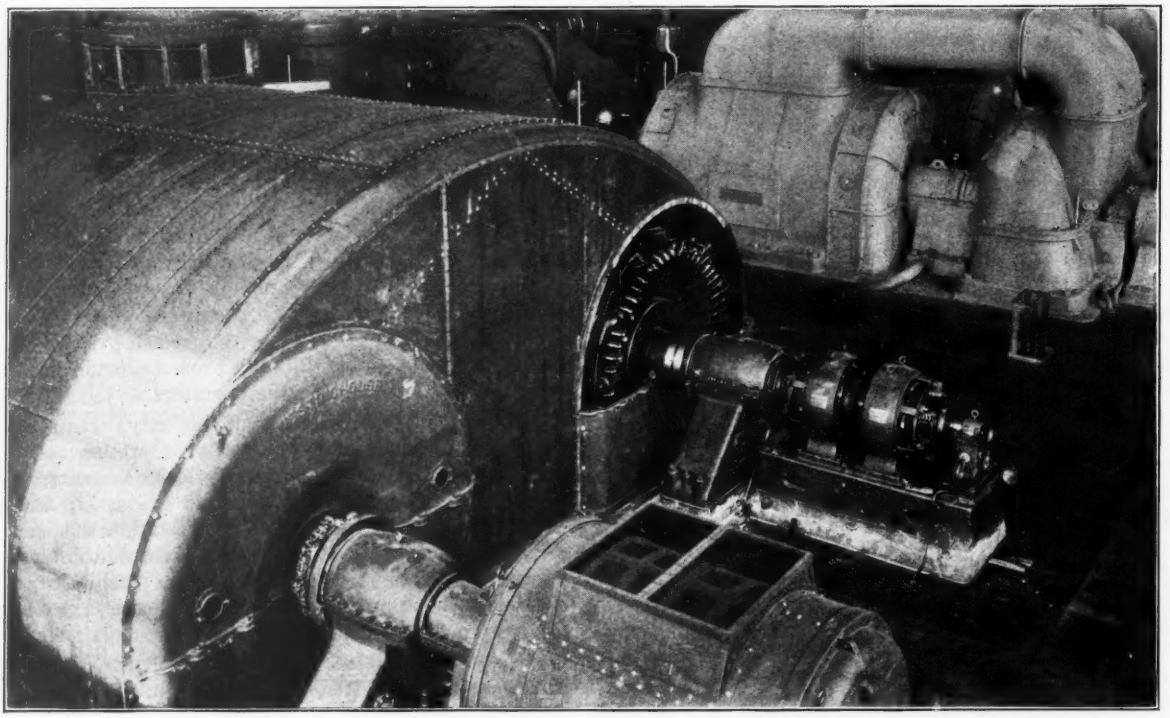


FIG. 13. A VIEW OF THE WESTINGHOUSE UNIT SHOWING THE ARRANGEMENT OF THE TWO GENERATORS IN A SINGLE CASING

are located in a plane midway between the two generators and below the level of the operating room floor. These blowers circulate the air through the generators and an extended surface cooler. Each blower is rated at 91,667 c.f.m., making the total capacity of the three units 275,000 c.f.m.

Features of the Brown Boveri Turbine Generator

A general idea of the arrangement of the Brown Boveri unit may be had from the photograph, Fig. 2. Considering the unit from the steam end, the high-pressure element is located on the left and the high-pressure unit on the right. The steam controlling gear is located in the form of a battery of valves on the center line of the high-pressure shaft.

The high-pressure spindle is built up of four short drums keyed to the shaft, each held in place by two patented elastic rings. The low-pressure spindle is also built up, consisting of 14 disks similarly keyed to the shaft.

Of particular interest is the construction of the low-pressure shaft, which in a unit of this size is necessarily of great proportions. Such a shaft, if made in the ordinary way, would naturally have a large mass with relatively small surface while the disks have a large surface and little mass. In warming up, there would naturally have been a time differential in the expansion of the two elements and as the disks are mounted on elastic rings, this differential might have resulted in rough running and necessitated a long starting period. In order to avoid any trouble of this nature, the low-pressure shaft is made hollow so that it can heat up quickly. This shaft is 26 ft. long, 36¼ in. in diameter and weights over 25 tons, without disks. It is bored out to a diameter of 15¾ in. at the center and 7⅞ in. at the ends.

Steam Controlling Gear

The steam controlling gear is located, in the form of a battery, on the center line of the h.p. turbine. There are six governor valves, each connected to the h.p. cylinder by 6 flexible steam pipes arranged in pairs in addition to one overload valve. There are two valve chests, each having its own stop valve.

Each main valve chest accommodates a 23.6-in. stop valve, a 15.8-in. and a 19.7-in. controlling valve, which, in conjunction with three similar valves, act as bypass valves and control the steam admission. The arrangement is shown in Fig. 8.

The unit is controlled entirely from the operating station through remote control, control being effected hydraulically by oil pressure which is controlled by a spring loaded centrifugal governor driven by the high-pressure turbine spindle. Steam is admitted to the steam chest through two hydraulically-operated main stop valves, each of which is furnished with a bypass valve, also hydraulically operated. From the main

Data on 1928 Installation at Hell Gate

STRUCTURES

Turbine room extension—Length, 70 ft.; width, 100 ft.; height, 124 ft.

BOILERS, SUPERHEATERS, ECONOMIZERS, AND AIR PREHEATERS

Make of boilers—Springfield.
Firing—Pulverized fuel.
Type of boilers—Cross drum, water tube, 3 pass with water walls; 3 drums per boiler.
Number—Three.
Areas and volumes per boiler—Water heating surface, 20,000 sq. ft.; water wall heating surface, 3800 sq. ft.; total heating surface, 23,800 sq. ft.; superheater surface, 4800 sq. ft.; furnace volumes, No. 81, 18,800 cu. ft.; No. 82, 21,840 cu. ft.; No. 83, 18,150 cu. ft.
Ratios—Water heating surface to boiler room floor area, 7.56; furnace volume to water heating surface, No. 81, .79; No. 82, .918; No. 83, .763; superheating surface to total water heating surface, .202.
Boiler pressure—275 lb. gage.
Make of superheaters—Superheater Co.
Type of superheater—Elesco, bent tube, convection.
Make of water cooled walls—Combustion Eng. Co.
Type of water walls—Fin.
Economizer data:
- Make—No. 81 and No. 82, Foster Wheeler Corp.; No. 83, Combustion Eng.
- Type—No. 81 and No. 82, Foster; No. 83, C. E. C. fin tube.
- Number—One per boiler.
- Square feet heating surface—No. 81 and 82, 26,136 (22 rows high, 18 rows wide, 22 ft. 0 in. long over rings); No. 83, 27,836 (56 rows high in two sections, 18 rows wide, 21 ft. 0 in. length of tubes).

Air preheater data:
- Make—Combustion Eng. Co.
- Type—Plate.
- Number—One per boiler.
- Surface—11,840 sq. ft.
- Capacity—456,700 lb. air per hour.
- Temperatures—Air, inlet, 70 deg.; outlet, 286 deg. Gas inlet, 820 deg.; outlet, 484 deg.

Construction of setting—Water cooled furnace walls insulated with 1⅞ in., 1800 semi-refractory, 4 in. Weber's No. 48 plaster, finished with ⅛ in. hard cement.

COMBUSTION EQUIPMENT

Make—Combustion Engineering Co.
Fuel preparation and burning:
- Mills—Raymond Impact No. 82, 4 per boiler, 12,500 lb. per hr. each.
- Burners—Tangent, 3 elements per burner, 4 burners per boiler, 1 burner per mill.
- Air supply—Primary, 15% of total, introduced at mill at 280 deg.; secondary, 85% of total, introduced at burner at 280 deg.
- Ash disposal—Furnace, hydraulic; flue gas, hydraulic.

FANS

Induced draft fan data:
- Make of fans—Sturtevant.
- Number—One per boiler.
- Capacity—275,000 c.f.m., 14 in. S. P.
- Fan drive—Motor drive, 1200 hp., Westinghouse, 870, 690, 435 r.p.m., 2300 v.

Forced draft fan data:
- Make of fans—Sturtevant.
- Number—One per boiler.
- Capacity (each)—155,000 c.f.m., 10 in S. P.
- Fan drive—Motor drive, 400 hp., Westinghouse, 870, 690, 435 r.p.m., 2300 v.

COAL HANDLING EQUIPMENT

Equipment:
- Two magnetic steel apron feeder conveyors, Link Belt Co.
- Two automatic recording scales, Richardson Scale Co.
- Two spiral conveyors, Link Belt Co.

Procedure—Equipment installed in two parallel systems with a capacity of 50 tons each of raw coal per hour.

PRIME MOVERS

	8	9
Unit No.		
Make	American Brown Boveri	Westinghouse
Type	Cross compound	Cross compound
Rated capacity, H.P. section	75,000 kw.	80,000 kw.
L.P. section	85,000 kw.	80,000 kw.
Speed, H.P. section	1800	1800
L.P. section	1200	1800
Blading	Reaction, stainless steel, tapered	Reaction, stainless steel, tapered
Bleed points	Two	Two
Purpose of bleeding	F.W. heating	F.W. heating
Type of generator	3 phase, 60 cycle, 13,800 v.	3 phase, 60 cycle, 13,800 v.
Generator rating, H.P. section	88,250 kv-a.	94,200 kv-a.
L.P. section	100,000 kv-a.	94,200 kv-a.
Ventilation	Closed type system, extended surface cooler, 2 blowers one on each main shaft, 264,500 c.f.m.	Closed type system, extended surface cooler, 3 motor driven blowers, 91,667 c.f.m. each.
Excitation	2 direct connected exciters—H.P. shaft, 270 kw., 300 v. L.P. shaft, 310 kw., 300 v.	2 direct connected exciters on H.P. shaft, 200 kw., 250 v. each.
Lubrication	4 oil cooler in series, rotary gear type oil pump, standby turbine driven centrifugal oil pump.	Griscom-Russell oil coolers, direct connected oil pumps, standby turbine driven oil pump.
House generator	None	One—Direct connected to L.P. shaft.
House generator rating		6250 kv-a., 5000 kw., 60 cycle, 3 phase, 2400 v.

BOILER FEED PUMPS

	8	9
Unit number		
Number installed	2	2
Make	Bethlehem	Dean Hill
Type	Weir type, horizontal, single suction, single stage.	2 stage, diffuser type
Drive	Turbine	Westinghouse Turbine
Capacity	2000 g.p.m. of 210 deg. F. water at 3600 r.p.m., and 500 lb. per sq. in. discharge pressure.	2000 g.p.m. of 210 deg. F. water at 2800 r.p.m., and 500 lb. per sq. in. discharge pressure.

FEEDWATER HEATERS

	8	9
Unit number		
Number installed	2	2
Make	Elliott Co.	Cochrane
Type	Cylindrical, closed, floating head	Cylindrical, closed, floating head
Surface, L.P. heater	5900 sq. ft.	5400 sq. ft.
H.P. heater	5900 sq. ft.	4350 sq. ft.
Tubes	¾ in. O.D.	¾ in. O.D.
Capacity at 160,000 kw., L.P. heater	1,690,000 lb-hr.	1,497,700 lb-hr.
H.P. heater	1,880,000 lb-hr.	1,705,000 lb-hr.

CONDENSERS

Unit number—8 and 9.
Make—Westinghouse.
Type—Double 2-pass, radial type, surface condenser.
Tube surface—137,500 sq. ft.
Tubes—32,000, ⅞ in. O. D., No. 18 Admiralty.
Sq. ft. tube surface per rated kw. of prime mover—.86.
Circulating pump data:
- Number per condenser—2.
- Make—Westinghouse.
- Capacity (each)—77,500 g.p.m.
- Drive—Direct connected, 500/190 hp., 40 deg. motor, type "C8," 2300 v., 3 phase, 60 cycles, 290/217 r.p.m.
- Capacity per kw. installed—.97 g.p.m. per kw.

Hot well pump data:
- Number per condenser—3.
- Make—Westinghouse.
- Capacity (each)—875,000 lb-hr.
- Drive—Direct connected, 100 hp., 870 r.p.m., 2300 v., induction motors.

Air pump data:
- Number per condenser—3.
- Make—Westinghouse.
- Type—3 stage, steam jet air ejectors.
- Capacity—64 c.f.m. at 29.5 in. vacuum.

valves, the steam enters the turbine through seven governor valves, two primary, two secondary, two tertiaries, and one quarternary, each opened by oil pressure and each controlled by a small pilot valve. In starting and shutting down the unit, a small controller is used for opening and closing the bypass and main stop valves.

Loads of 50,000 kw. and under are carried by the primary valves, from 50,000 to 90,000 both primary and secondary valves are opened and at full load, 160,000 kw., all seven valves are opened.

In providing these turbines, it was necessary to design them with a fairly flat efficiency curve. A full load capacity of 160,000 kw. was required, while a flat efficiency curve was stipulated for between the loads of 55,000 and 90,000 kw. Hence, the units are required to take an overload of 70,000 kw.

The load at Hell Gate is subject to extremely rapid changes. At times of sudden thunder storms, the load demand on the system may rise as much as 350,000 kw. in a few minutes. In one case of a snowstorm which commenced in the morning at the moment of changing shifts, the load rose for three hours at the rate of 3000 kw. per min.

To meet this demand for a very flat efficiency curve, some sacrifice of maximum efficiency was necessary, as shown in the accompanying tabulation:

Load—kw.	55,000	90,000	130,000	160,000
Steam consumption lb. per kw-hr. at 265 lb. gage, 200 deg. F. suph. and 29 in. vacuum	10	9.8	10.2	10.7

The corresponding efficiency ratios at the above loads, with the generator efficiencies also tabulated, are as follows:

Load—kw.	55,000	90,000	130,000	160,000
Gen. eff.	93.8	95.75	96.4	97.0
Power factor	0.8	0.8	0.8	0.85
Eff. ratio at turbine from stop valve to condenser	82.7	82.7	80.0	77.4

The foregoing figures include the energy required for the ventilating motors. When the unit is operating at 90,000 kw. and bleeding steam for feedwater heating, the heat consumption of the whole machine is 11,660 B.t.u. per kw-hr., corresponding to a thermal efficiency of 29.25 per cent from the steam at the main stop valve to the switchboard.

When operating at maximum load, without bleeding, the Brown Boveri machine is designed to use 1,710,000 lb. of steam per hour. This corresponds to 215,000 gal. of boiler feedwater per hour.

Details of the Westinghouse Unit

The Westinghouse turbine is rated at 165,000 kw., the slightly higher rating being due to the fact that in addition to the main generators, this unit also drives a 5000-kw. house generator. This house generator and its exciter are attached to the lower-pressure element. The high-pressure element carries the two main exciters, one for each main generator.

As already explained, the two generators are placed side by side and are enclosed in a common sheet metal casing with the three ventilating fans between.

This machine, complete, weighs 1241 tons or about 7.5 lb. per 1000 kw. The high-pressure cylinder structure consists of cylinder base and cover, each made in two parts, a high-pressure and a low-pressure end, which are bolted together during construction and thereafter each treated as one piece. The cylinder is supported on four lugs integral with the cylinder base and located as near as possible to the plane of the horizontal flange and resting on suitable pads or machine surfaces on the coupling end and thrust end bearing pedestals respectively. These lugs are free to slide on the pads in any direction, consequently the cylinder is free to expand without restriction. The low-pressure cylinder consists of a base and cover each made in three parts and enclosing a loose blade ring which carries all the stationary blading except the last row of guide vanes at either end. The cylinder is anchored at the coupling and bearing pedestal and is supported on four chairs each of which is free to expand laterally or axially.

Rotating blades throughout the turbine, both high-pressure and low-pressure, are made of stainless steel, and the cylinder or stationary blading is of stainless steel as well, except for the last rows of guide vanes in the low-pressure cylinder, the final row being made of cast iron and the two preceding rows of cast manganese bronze.

All the spindle blades, except the last three rows at either end of the double flow low-pressure spindle, are fastened with a T-head fastening which has been in use for some years past with highly satisfactory results. The last three rows at either end of the low-pressure turbine are secured with a new type of fastening of a high degree of efficiency. This has been designated by the term "side entry blading." These blades have a curved serrated root, the serration taking the form of a buttressed thread, and instead of being entered in a circumferential groove in the customary manner, they are entered axially into grooves machined across the periphery of the blade disk.

Although, at the time this order was placed, the Westinghouse Company had already developed the so-called impeller type oil governor, the engineers of the United Electric Light & Power Co., because of the excellent regulating characteristics of the older fly-ball governor and perhaps with a view to station uniformity, preferred to have this turbine equipped with the fly-ball governor which for years past has been this manufacturer's standard. The valve control system, however, embodies a number of new features.

The steam supply is brought to the unit through two 28-in. lines each connected to a steam strainer and a throttle valve. Six inlet valves arranged in two groups, control the admission of steam to the high-pressure turbine. These valves are arranged to open in four steps. One primary valve and one secondary valve each admit steam to a nozzle group in the impulse element. For the tertiary load, two valves open together and admit steam to the impulse wheel chamber, bypassing the impulse element. This combination will carry loads up to 120,000 kw. For the maximum load of 165,000 kw., the fifth and sixth valves open together, admitting steam between the first and second reaction blade groups. Each of these valves is actuated by an independent operating piston controlled by an individual relay. These relays in turn are cam actuated from a main operating piston controlled by the main governor relay.

Motive oil for the relays and operating cylinders is supplied by the main oil pump. In this connection, a feature of particular interest is the arrangement of the lubricating system. The main oil pump, instead of being of the usual vertical gear or rotary type, driven

from the turbine shaft by means of a worm and gear, is a centrifugal impeller mounted directly on the main turbine shaft. Employment of a centrifugal pump for this purpose has been impracticable hitherto because of the fact that the oil reservoir is of necessity located at some distance below the shaft centerline and no satisfactory means were available for priming the centrifugal impeller or of insuring the maintenance of a positive suction head. A practicable and satisfactory combination of this kind has now been achieved by employing part of the oil discharge by the impeller as motive fluid in an oil ejector. This ejector raises from the reservoir a large quantity of oil at low pressure and delivers it under a small positive head to the impeller inlet chamber. Since an auxiliary oil pump must be used in any case during starting and stopping, when the speed of the main oil pump is too low to produce the required pressure, this system provides a compact and self-contained lubricating arrangement in which the only moving element is an ordinary centrifugal pump runner and by means of which all driving worms and gears or other wearing parts are eliminated.

The auxiliary oil pump is a vertical centrifugal pump driven by a small turbine and provided with automatic control by means of which it will be started up whenever the lubricating system pressure falls below a predetermined safe limit.

The steam chest is anchored solidly to the foundation, provision being made to take care of the expansion of the steam chest parts. Connection is made from the steam chest to the high-pressure turbine by means of a number of long relatively flexible pipe loops underneath the floor level. The effect on the turbine of temperature changes is further minimized by making the inlet loops of such length that in the initial cold condition, the high-pressure turbine will be subjected to a contraction strain, thus approximately halving the value of the ultimate expansion strain at maximum temperature.

Condensing Equipment

Since the low-pressure elements of both units are of the double flow type, each low-pressure element is provided with two exhaust connections. Each of these connects to one half of the double condensers, which are installed directly below.

Condensate is removed from the condensers on each unit by three centrifugal hot well pumps, each having a capacity of 875,000 lb. per hr. and driven by 100-hp. motors. These three pumps discharge into a single header which connects directly with the condensers of the steam jet evactor on that unit. Passing through the evactor condenser, the condensate next enters the low-pressure extraction heater where it is heated by steam extracted from the fifth stage of the low-pressure turbine and then is delivered to the high-pressure heater which is fed from the high-pressure turbine exhaust. From the high-pressure heater, the water is delivered to the boiler feed pumps and then to the economizers.

Condensate produced in both of the heaters is also delivered into the feedwater line. From the high-pressure heater, condensate is trapped and delivered into the hot well of the low-pressure heater, where it mixes with the condensate produced in that heater. This combined condensate is pumped into the feedwater line at a point just ahead of the high-pressure heater.

Makeup water is supplied to the system from a surge tank, connected to the system between the evactor condenser and the low pressure heater.

Electrical Features

In providing switching facilities for handling the increased output of the station due to the addition of the two new turbine units, it was necessary to alter the existing system of bus arrangement. As originally planned, there were nine bus sections, sections 1 to 4 of which were on 25-cycle service and sections 5 to 9 on 60-cycle service. Just previous to the 1928 extension, all the bus sections with the exception of section 9 were in use, section 9 having been reserved for the last generating unit, No. 8. The new extension, however, included two new generators, hence it was necessary to alter the existing bus arrangement so as to provide one whole bus section for each of the new units.

This was accomplished by the method shown in Fig. 14. In this illustration, at A, is shown a simplified

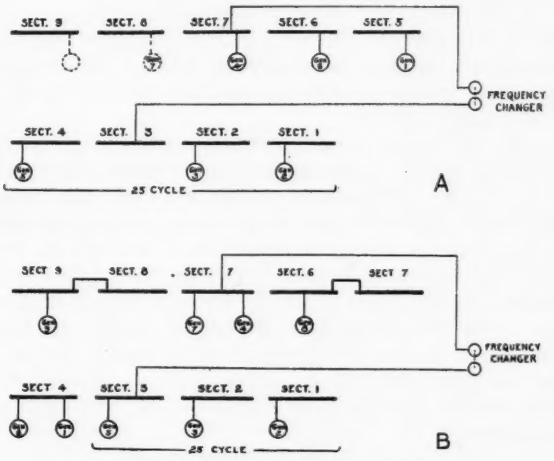


FIG. 14. SINGLE LINE DIAGRAM INDICATING CHANGES IN THE ELECTRICAL SYSTEM

diagram of the existing bus arrangement before the 1928 extension. At B is shown another diagram showing the new arrangement of the 60-cycle circuits. Generator No. 5, a 25-cycle machine originally connected to bus section No. 4, is now connected to section No. 3. This change made it possible to use section No. 4 for 60-cycle service, so it was reconnected so as to take current from generators, 1 and 6. The connections from the other machines were changed so as to leave bus sections No. 5 and 6 available for one of the new units (unit No. 8). The 165,000-kw. Westinghouse was connected to bus sections No. 8 and 9. Current is generated by the new machines at 13,000 v. which is that of the 60-cycle station system.

With the completion of this extension and possibly the addition of two additional boilers next year, Hell Gate will have reached its ultimate capacity.

In conclusion, acknowledgment is made to the officials of The United Electric Light & Power Co. for many courtesies extended in the collection of material used as the basis of this article and for supplying the photographs and drawings. Credit is due, also, the Westinghouse Electric & Mfg. Co., for furnishing information on the construction of its turbine.

Edgar Station

700 Lb.—1200 Or 3200? Prove To For Kw. At Low

HIGH PRESSURE has changed its meaning rapidly during the past few years. Not so long ago, it referred to anything above 150 lb. Then it changed to 250, 400 and now anything under 500 lb. would be considered as ordinary pressure. For latest large-station practice, probably 500 to 600 lb. may be considered as an established standard but the 800 to 1500-lb. stations are still considered by many as experimental and the 3200-lb. plants as commercial laboratories. Do the facts justify this mental attitude?

Like all advances, extra-high pressure had its beginning far back. In reviewing the advances, Mr. Orrok has pointed out that Ernest Albans worked with pressures up to 1200 lb. as far back as 1840 and that in 1897 DeLaval ran a 50-hp. impulse turbine at 1420 lb. and a 100-hp. unit at 2840 lb. and 750 deg. from a flash type boiler. Industry was not ready for such radical changes nor could durable equipment for such conditions have been built at a commercial cost or in commercial sizes but the latest development of these experiments is seen in a 600-hp. unit running at 6000 r.p.m. and 1420 lb. pressure.

What High Pressure Offers

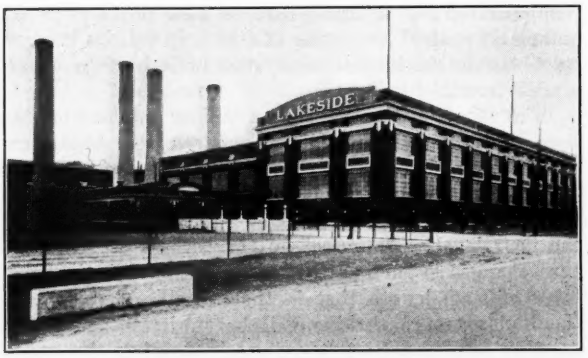
Naturally, the question arises, why incur extra cost of installation and upkeep when pressures of the 600-lb. range are showing satisfactory economy? The answer is to squeeze the last fraction of a kilowatt-hour out of a heat unit. High temperature peps up a heat unit and gives it greater capacity for work. And it is found by studying a temperature-entropy diagram that the higher the pressure, the more kick the heat unit will have before it gets fagged out at the low limit in the condenser.

The low limit, at which the heat unit gives up the fight, exhausted, has been pulled down with high-vacuum condensers as far as it can go, so the only way to get additional work is to shove up the initial pressure and temperature.

Here are encountered certain physical limitations: properties of the materials available for boilers, superheaters and turbines, condensation in the steam during great expansion and the complication of plant to handle high pressures and temperatures yet avoid increasing the possibility of interrupted service.

All these have, however, been studied and tried out so that we have a clear idea of what can be done.

Comparing results at 500 lb. with those for higher pressures we find from such authorities as Moultrop, Dillon, Jowett and Collings, who speak from experience as well as careful analysis, that without reheating the steam and with stage heating of feedwater, pressures above 400 lb. have no economy, while studies made for the Holland plant showed that 400 lb. without reheat and with two or three-stage feed heating indicated better dollar economy than 550 lb. with one reheating, the gain in heat efficiency being offset by increased fixed charges.



Lakeside Station

As an index of the thermal advantage, Dillon has shown that for 700 deg. initial temperature, 1 in. exhaust pressure and two-stage feed heating, the possible thermal efficiency for 500 to 700 lb. initial pressure and no reheating is 30 per cent; for 500 lb. with one reheat is 31.2 per cent; for 700 lb. and one reheat, 32.5 per cent; and for 1200 lb. and reheat, 33.5 per cent. Considering turbine and Rankine efficiencies, this works out as follows:

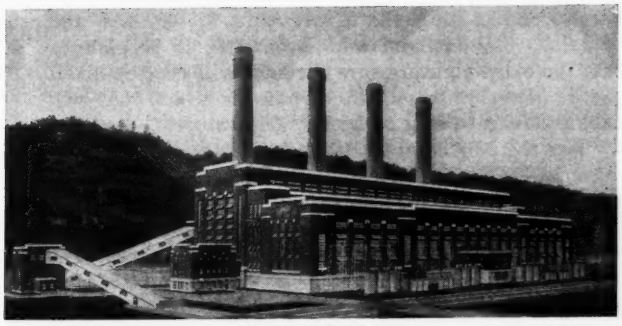
Pressure lb.	Turbine Eff., Per Cent — no reheat	Turbine Eff., Per Cent — one reheat	Rankine Eff., Per Cent — no reheat	Rankine Eff., Per Cent — one reheat
500	80	83.5	37.5	37.7
700	76	83	38.2	39.3
1200	66.5	82	40.2	40.4

Collings shows that, with stage heating to 60 deg. below boiler temperature, initial temperature of 700 deg. and reheat at ⅓ throttle pressure to 700 deg. the heat values on a purely thermal basis will be:

Pressure lb.	B.t.u. per kw-hr. turb.	B.t.u. to aux. per kw-hr.	B.t.u. kw-hr., net output
500	10,750	515	11,265
700	10,300	495	10,795
1200	10,000	530	10,530

With losses taken into account, Moultrop has shown that up to 1925, with pressures of 500 to 600 lb. the possible net output was 1 kw-hr. for 14,000 B.t.u. With 1200 lb. this was lowered to 13,000 B.t.u. He also states that, compared to 400 lb. with no reheat but

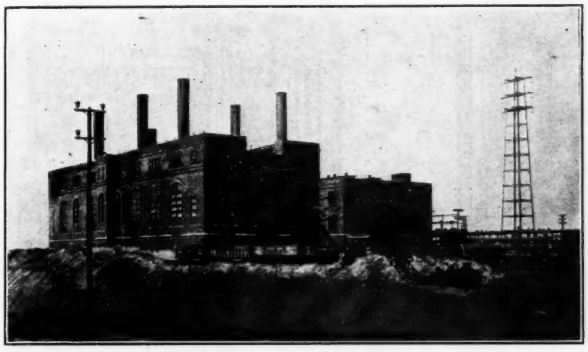
1400—1800 Which Will Be Best *Making Cost*



Holland Station

stage feed heating, the use of 1200 lb. with reheat at 350 lb. to 750 deg. will show 12 per cent gain and with reheat to 900 deg., 15.5 per cent gain.

Will higher first cost offset thermal gain? This question is vital but analysis and experience seem to return a negative answer. Moultrop has shown that of the cost of a station, only 41 per cent is increased by



Northeast Station

going to extra-high pressures. This includes the turbine-generator and boiler plant equipment. Switchhouse and gear cost the same regardless of steam pressure and account for 22 per cent of total plant cost. On the other side, for buildings to house boiler and turbine plant, for fuel and ash handling and draft equipment, also for the condensing system, a total of 37 per cent of the plant, cost will be decreased by extra-high pressure because of increased capacity of equipment and less fuel and steam to be handled.

Peculiarly, analysis of the Holland plant showed that the first cost of a 1200-lb. turbine-generator would be less per kilowatt capacity than that for a 550-lb. compound unit with reheat. Also the use of high pressure permits more of the total heat transfer surface of an installation to be provided in economizers and air preheaters for which the cost per square foot is much less than in boiler heating surface. Economizers made up 17.6 per cent and air heaters 46.3 per cent of the total in the plant as against 12 per cent in boilers and 6.9 per cent in superheaters while cost per square foot as compared with boiler surface was 23.2 per cent for economizers and 4.4 per cent for air heaters.

While experience has shown that the high-pressure plant can operate at half load with as good comparative heat economy as one for lower pressures, it is also shown that, when operating on an interconnected system, it is unwise to install spare high-pressure boilers. Outage for boilers is small and it is better to carry load temporarily by forcing the units in service or by transferring load to moderate-pressure plants of the system.

Typical Practice

Pioneer among American plants, the Edgar Station began in 1925 with a 3150-kw. unit at 1200 lb. pressure and 700 deg. and no air preheating. As a result of experience, pressure was raised to 1400 lb., temperature to 733 deg. and output to 10,000 kw. in the second installation, 1928. And for the third installation, now nearing completion, 1400 lb., 750 deg. and 12,000 kw. were selected. Other developments are shown in Table I.

TABLE I. DATA OF EDGAR STATION UNITS

Equipment	1st Unit 1926	2nd Unit 1928	3rd Unit 1929
Boiler Press. lb.	1200	1400	1400
Boiler Tubes			
Lower bank	2" by 15'	3 1/4" by 19'	3 1/4" by 19'
Upper bank	2" by 15'	2" by 17'	1 pass
Boiler Drum	48"-dry pipe	48"-dry pipe	52"-12 nozzle
Boiler h.s., sq.ft.	15732	15093	6971
Furnace walls	refrac.	3 sides water	3 sides water
Water wall surf.sq.ft.	0	1235	1206
Superheater type	4-pass hor.	3-pass hor.	4-pass vert.
Superheater surf.sq.ft.	2923	3483	5096
Superheat deg.	700	733	750
Economizer, type	steel tube	return bend	hairpin bend
Economizer surf.sq.ft.	11,091	5596	9634
Economizer in temp.deg.	250	420	420
Air Heater surf. sq.ft.	0	33,032	29,665
Reheat, deg. lb.	700-370	750-370	750-370
Reheater surf. sq.ft.	5938	8879	6936
Total h.s. sq.ft.	35,684	67,318	59,508
Steam, lb. per hr.	143,000	250,000	300,000
Turbine capac. kw.	3150	10,000	12,000
Turbine type	20 stage 1 valve	16 stage 1 valve	14 stage 5 valve

Practice in other stations has been within the limits thus tested out and data of typical stations are given in Table II. It is notable that at Holland and Deepwater the entire plants were designed originally for extra-high pressure, while other plants have had the extra-high pressure units superimposed on equipment already in service. At Holland an unique feature is reheating partly by live steam and partly by hot gases. At Deepwater, one high-pressure unit is to be run non-condensing, the exhaust being sold to a near-by industrial plant.

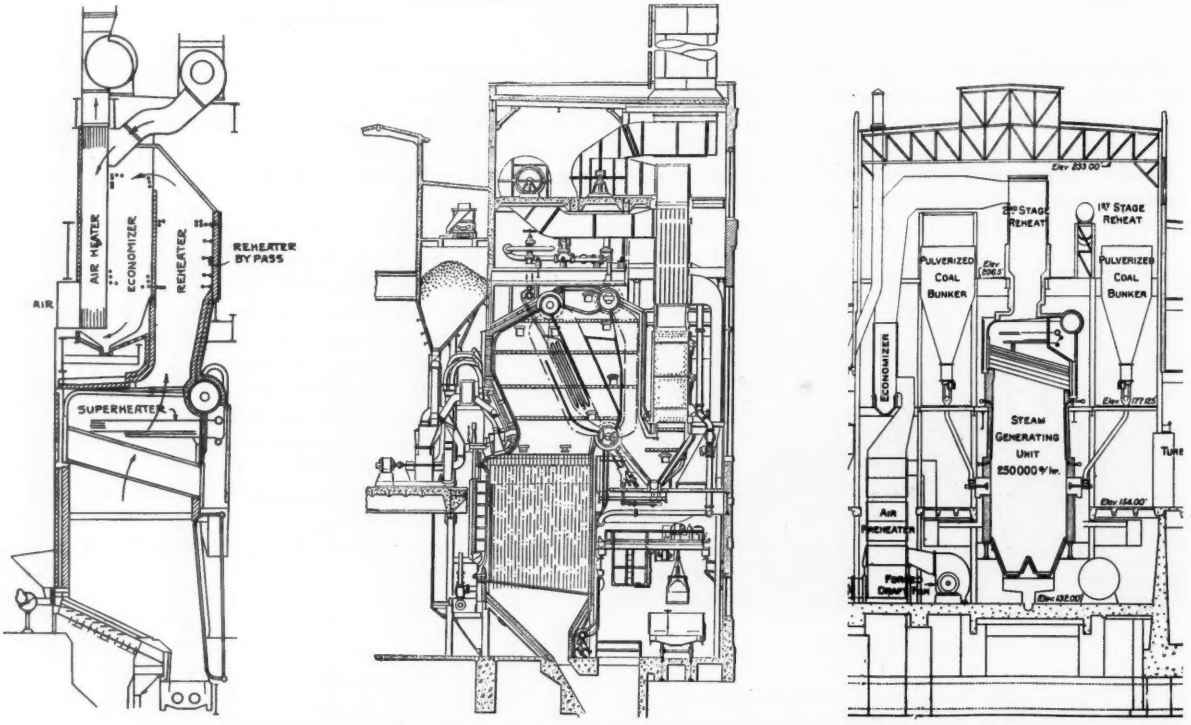
One distinct advance in units operating on varying load is the use of five valves for steam admission to the turbine in place of the one valve used first. The gain is shown by a comparison of estimated steam consumption for Deepwater units to run at 1200 lb. and 725 deg. For a 10,000-kw., one-valve unit the consumptions at ¼, ½, ¾ and full load were, 88, 57.5, 46.5 and 40 lb. of steam per kilowatt-hour developed by the

high-pressure unit: while for a 12,500-kw. unit with five valves for like loads the figures were, 53, 43, 41.5 and 41.5 lb. For Holland and Deepwater it is planned that the extra-high pressure turbines will develop about ¼ the power of the 400-lb. turbines to which they will exhaust, reheat being to initial temperature.

For the Northeast Station, figures given by Jowett show 13,810 B.t.u. per kw-hr. for the high-pressure unit as against 16,800 for the 300-lb. units. Cost for the 1400-lb. boiler was $30 per kw. of total power and for the 1200-lb. turbine $31 per kw. These costs were 31.6 per cent more than for a 300-lb. installation of like

Creep is a comparatively new but very real bug-a-boo. It is the tendency of ultimate stress and elastic limit of a material to become lowered under long continued subjection to high temperature and, while probably present at all temperatures, it starts being troublesome at fairly well defined temperatures for different materials.

For instance, Davey states that for 35 per cent carbon steel, creep effect becomes evident at 400 deg. Up to 500 deg. it is not great, but at 750 deg., creep reduces ultimate strength from 83,000 lb. down to 40,000 lb.; at 900 deg., the reduction is from 66,000 lb.



TYPES OF HIGH-PRESSURE INSTALLATIONS: EDGAR THIRD UNIT, NORTHEAST, HOLLAND

capacity but the fuel saving was three times the fixed charges on the greater cost.

European Practice

While American practice has stopped at 750 deg., several European plants are using up to 860 deg. although at pressures of 750 to 900 lb. In contrast, some units are being tried out at 3200 lb. boiler pressure, although the turbine pressure is 1420 lb. and temperature 750 deg. Tenders have been made for plants to operate at 900 deg. but at moderate pressure.

No especial trouble has been encountered over several months of operation but it seems unlikely that there will be any widespread development at these extreme conditions until experience gives more data as to cost and difficulty of upkeep over extended periods.

Why Stop at 1500 Lb.?

For one thing, Moultrop estimates that commercial economy will not be increased with pressures above that figure. Another limit is the safe stress of available materials and high cost of construction when building the large size units demanded by modern plants.

down to 16,000 lb. Strength decreases as temperature rises, even without the creep effect, but that effect greatly augments such decrease, after a period of service. Obviously this effect becomes of more concern as pressures are increased.

Just how creep acts and its effects are not certain but, as a guideboard, the "temperature margin" has been discussed. This is the difference between actual temperature of the metal when in use and the temperature at which the creep effect becomes serious. Orrok gives as a safe value 200 deg. F. He states that, for materials now used, the temperature margin at 200 lb. pressure is 480 to 600 deg.; at 1400 lb. this drops to from 70 to 185 deg. and in 1200-lb. superheaters to 100 deg. The result is shorter tube life and the remedy more rapid circulation to carry away heat faster so as to reduce the temperature of the tubes. Also use of special materials whose dangerous creep temperature is higher.

Davey gives the serious creep temperature for chrome-nickel alloy steel as 500 deg. and Mellanby states that this material is as safe at 1500 lb. or 900 deg. as is cast steel at 250 lb. or 400 deg.

In operation of extra-high pressure equipment, it has been found that the same care and attention are required as for ordinary pressures, with especial care to insure clean feedwater. Pure condensate and distilled make-up water have been found essential on account of the high rate of heat transmission and the necessity for keeping tube surfaces clean.

At Lakeside, leakage in the condenser caused some scale formation in the boiler and it was found that, with 1/32 in. of scale, operation was feasible but that 1/16 in. of scale caused failure. Excess of oxygen above 0.45 cu. centimeters per liter caused corrosion. When alkalinity of 781 parts per million was maintained and oxygen reduced to 0.055 cu. cent. per liter, corrosion stopped. There was, however, a slight alkaline deposit in the superheater and coating on turbine blades which lowered the turbine capacity materially. With alkaline solids appeared but did not seem to increase. One source of loss is interstage leakage. By checking up on and reducing this the ratio of 1200-lb. power to 300-lb. power was raised from 0.742 to 0.80.

In early plants, overheating of tubes at local points, due to intense heat transmission, caused splitting and deformation, which was overcome by better shielding of tubes and change of furnace to avoid creating local excessive temperatures.

Among accessories, the feed pump is, perhaps, the most bothersome problem, as the high pressure has called for several-stage handling, resulting in an overly large and costly equipment, but performance is satisfactory. Progress is being made toward more compact and less expensive designs.

From recent designs, it would seem that heat transfer in the auxiliary operations of feedwater and air

TABLE II. DATA OF REPRESENTATIVE HIGH-PRESSURE AND TEMPERATURE PLANTS

Name of Plant	Edgar 1st unit	Edgar 3rd unit	Lakeside	Northeast	Holland	Deepwater	Langerbrugge	Wernigerode	Siemenstaadt
Boilers									
Type	cross drum	cross drum	Stirling	Ladd 3 drum	cross drum		cross drum	Schmid	Benson
Press. lb.gage	1260	1400	1300	1400	1400	1350	750	870	3200
Output lb. per hr.	143,000	300,000		300,000	250,000	290,000			
Heating surf. sq.ft.	15,732	15,093	28,532	16,950	7,928	9,623	4,765	1,420	2,329
Furnaces									
Walls	Refract.	Water	Water	Water	Water	Water	Refract.	Refract	Refract
Water wall surf.sq.ft.	0	1206	1544	3295			0	0	0
Superheaters									
Type	4 pass hor.	4 pass vert.		incl.tube	hor.				
Temperature, deg.F.	700	750	730	725	750	725	842	860	752
Heating surf. sq.ft.	2923	5096	930	2650	4560		1172		1420
Economizers									
Type	steel tube	hairpin	none	fin tube	tube	return bend			
Surface sq.ft.	11,091	9634		10,891	11,880	18,326		210	3280
Temp. in. deg.F.	250	420			430				
Reheater									
Type	convection	convection	radiant	radiant	steam conv.	sep.boiler			
Surface sq.ft.	5938	6936	933		1508 11,450	4811			
Pressure lb. gage	370	370			425 425	385			
Outlet Temp. deg. F.	700	750	720	735	750	725			
Total heating surf.sq.ft. of unit	35,684	59508							
Turbines									
Type of high press.	20 stage	14 stage	20 stage			14 stage			9 stage
Steam press. lb.gage	1200	1300	1250	1200	1200	1200			1325
Temp.initial deg. F.	700	750	725	725	750	725			752
Exhaust press. lb.gage	370	370	325	315	400	385			200
Rating kw.	3150	12000	7500	10,000	11,800	12,500			1000
Air Heater									
Type	none	tube	plate	plate	plate		tube		plate
Surface sq.ft.	0	29,665	20,160	39,270	32,450		4900		
Temp. out, deg.F.			650	400					

cut to 383 p.p.m. and oxygen held at 0.03 cu. cent. per liter and with baffles in the steam drums ahead of outlet to the superheater, all troubles ceased.

In the earlier operation of the first installation at Edgar Station, slugs of water sometimes came over when boiler feed was hand regulated. This has been overcome by special automatic regulator design. Also there was slagging on the lower tube bank, due to the small spaces allowed between the 2-in. tubes. With the larger tubes of later installations, this has not occurred.

Deposit of iron oxide powder in the tubes and on turbine blades was found due to corrosion in the economizer from excess oxygen in the feedwater, which was remedied by deaeration.

On the mechanical side, anticipated difficulty with valves, joints and piping has not materialized. Fittings tested by X-rays have been satisfactory from the start and the slight trouble from defects in those not so tested has been quickly overcome. Hand-hole gaskets have leaked some but this has happened even at ordinary pressures. It was remedied by pressed asbestos or other form of high-pressure gaskets.

Gage glasses of special design were needed and have been developed.

Turbine vibration was not violent and has been overcome. In some units blade and nozzle deformation heating will be further developed, leaving less for the boiler structure proper. A high-structure boiler with air-heater, economizer and superheater built as a unit and a single boiler unit large enough to supply a turbine unit will aid simplicity of plant and piping arrangement.

So far as United States practice is concerned, it would seem to be stabilizing in the extra-high pressure field at 1200 to 1400 lb. and 750 deg. European operation at 800 deg. and above must be considered as commercial experimenting not yet sufficiently proved to be dependable for any considerable part of a station's capacity. Of particular interest is the announcement recently made, as noted elsewhere in this issue, that The Detroit Edison Co., at its Delray Power House No. 3, plans to experiment with a 10,000-kw. British Thomson-Houston turbine taking throttle steam at 400 lb. pressure and a total temperature of 1000 deg. from a separately-fired superheater.

Results from the Rugby, Eng. plant to be equipped with Benson boilers for 3200 lb. and with an 18,000-kw. turbine-generator unit to run at 1764 lb., 910 deg. F. and 3000 r.p.m. will be looked for with great interest. Makers express readiness to guarantee boilers for 900 deg. but accessory equipment and the durability of plants operated at that temperature are as yet uncertain.

Care and Maintenance of Hydraulic Turbines

INSPECTION SHOULD DETERMINE CONDITION OF RUNNERS, GATE MECHANISMS, GOVERNORS AND ACCESSORIES AND PROPER ADJUSTMENTS AND REPAIRS MUST BE MADE

IN ANY hydroelectric plant, proper care of the water wheels and their various accessories is just as essential in maintaining the efficiency of the station as is the corresponding care given to steam turbines. Despite the fact that water wheels rotate at comparatively low speeds, when compared with steam turbines, the same factors of balance, clearances, wear and pitting must be considered.

Many of the details of water wheel installations are different, not only because of differences in manufacturers' designs but also because, even with turbines of the same general design, the manufacturer may make slight modifications in each separate installation to meet differences in requirements. Any procedure for care and maintenance of water-wheels should for that reason be determined to some extent by the design; only the most general rules can be laid down.

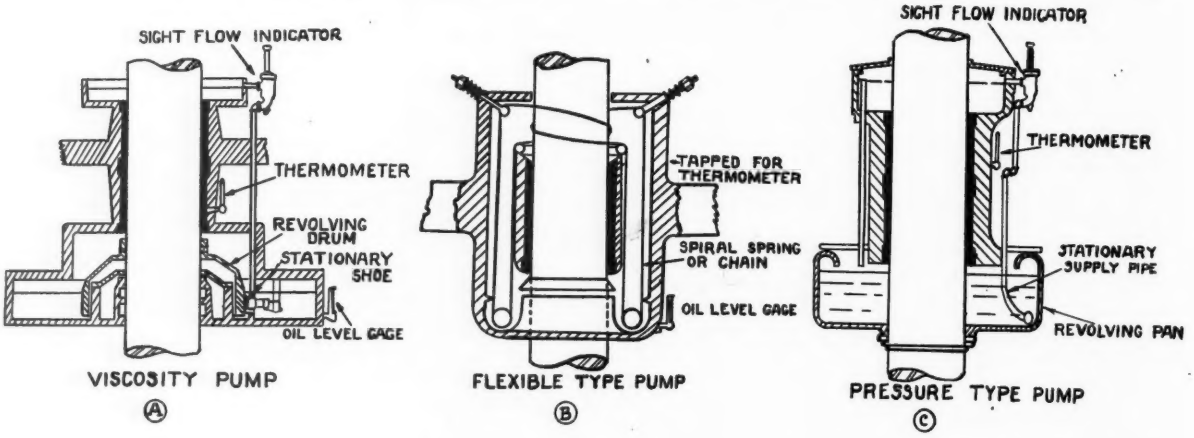


FIG. 1. THREE TYPES OF PUMPS TO GIVE INDIVIDUAL OIL SUPPLY TO BEARINGS. A—VISCOSITY PUMP; B—FLEXIBLE TYPE PUMP; C—PRESSURE TYPE PUMP

Considering the work they do, says Wm. W. Tefft,* hydraulic turbines receive less attention than other types of prime movers. This seems to be more true in industrial hydroelectric plants than in central stations. Open-flume turbines have been found operating two or three years without inspection; during this time guide vanes or links may have broken, thus allowing water to be wasted and main bearings may have worn badly, allowing the runners to rub, breaking the runners or causing serious vibration.

Mr. Tefft recommends that open-flume turbines be shut down for inspection every four or six weeks, this frequency depending somewhat on the number of units in the plant. By inspecting one unit a week, on Sunday or at some other convenient time, a good schedule can be maintained.

There is, of course, a wide divergence in maintenance or overhauling practice among various operating companies. Some companies have no prearranged schedule of overhauling. Annual, semi-annual or monthly inspections are made, taking the equipment out of service for the smallest possible time to do this, but not taking it out of service for overhauling until inspection reveals a condition that must be remedied at once. At the other extreme are companies with regular schedules for overhauling as well as inspecting, adhering to these schedules as closely as possible. Frequency of overhauling in such cases may be changed from time to time, as a result of improvements, particularly in items minor in themselves but necessitating outage of the entire unit for their repair. In general, most companies endeavor to do their major overhauling either at the season of lowest water flow or, if there is no such period, at the season of lowest load demand.

During inspections, several important points must be given attention. Water passages around runner and guide vanes should be cleared of any foreign matter. Runner clearances should be checked with thickness gages and the main shaft bearings adjusted to make the runner central. Gate mechanism should be inspected to see that there are no broken or worn links and that all gates close tightly. Regulating mechanism connections are usually lubricated by grease cups or alemite fittings and these fittings should be inspected, cleaned, if necessary, refilled and every precaution taken to ensure that lubricant will reach the bearings, not only to lubricate them but also to prevent rusting. The runner should be inspected for pitting, which will be discussed later. All foreign material should be removed from flume or penstock. The drains should be inspected for leakage and everything put in proper condition for refilling the flume.

One reason why open-flume turbines receive less attention than they deserve, says Mr. Tefft, is because of the difficulty of raising and lowering head gates. Motor-operated gates would, in such case, pay for themselves in time and labor and in the better inspection that they would make possible.

As pointed out above, it is not desirable, because of differences in conditions, to attempt any wide stand-

*Hydroelectric Handbook, by Creager & Justin.

ardization of inspection and maintenance methods in various points. Tables I and II, however, show two inspection sheets used by two large companies, which show the various items that are to be looked at during an inspection and which give some idea of the general procedure that may be followed.

Gate mechanisms of the outside type, with the actuating mechanism on the turbine cover plate, are usually fitted with some form of grease cups or alemite fittings as noted above. These are usually turned down or greased from one to three times a day. This frequency depends, of course, on the amount of regulating done by the mechanism and, to some extent, on the character of the water passing through the turbine.

General procedure for turbines of the spiral case type is the same as for open flume turbines, as noted above. They are often inspected every two or three months. The water passages are to be cleaned, guide vanes and runner inspected for pitting, runner tested for clearance and bearings adjusted to center the runner, guide vanes tested for leakage, and so on.

Main bearings of vertical turbines are often of the water-lubricated lignum-vitae type. Often the cooling water for these bearings is taken from two sources; one a hole tapped in penstock or turbine case, the other a reservoir, a pumping system, a well or a settling basin. In many rivers, the penstock supply is unfit for such use during freshet flows, as it may contain small sticks and leaves; in winter frazil ice may cut off the flow to the bearing. Water from a penstock or river, of course, can be passed through a fine screen before going to the bearing; a duplex screen arrangement is desirable so that the flow of water can be maintained while the screen is being cleaned. Sight flow indicators and alarms in bearing circulating-water pipe lines are considered an absolute necessity by most operating engineers.

Bearings lined with rubber are sometimes used on water wheels; these are lubricated with water and it is claimed that the same care does not need to be exercised to eliminate grit as is required with the lignum-vitae type.

Babbited, oil-lubricated bearings are also used for this service. These are lubricated with oil by various types of lubricating systems, sometimes of the central type and sometimes of the unit type. Proper sight flow indicators, bearing temperature indicating devices and electrically-operated "no-flow" alarms are usually considered absolutely necessary for such bearings to keep the operator fully informed of their condition. Cooling coils are often provided in these bearings, where radiation from the housing alone would not be sufficient to dissipate the heat generated.

During operation, the various flow indicating devices on oil and water lines are watched carefully. During inspection, the pipe lines, strainers, valves, pumps and other parts of the system should be examined to make sure that they do not need overhauling. In case they do, an auxiliary oil system is sometimes provided so that maintenance work on the main lubricating system may be carried out without shutting down the unit.

Individual oil pumps for water wheel and generator steady bearings are usually of one of the following types, arranged to start pumping as soon as the shaft begins to rotate:

Gear type, belt or gear-driven.

Plunger type, cam-driven.

Viscosity type, revolving drum and stationary shoe.

Flexible type, chain or spiral spring operated by shaft.

Pressure type, sump revolves with main shaft, supply pipe stationary.

Figures 1A, B and C show the three latter types; points needing attention during inspection and overhaul are obvious.

TABLE I. WORK SHEET FOR WATER WHEEL INSPECTION USED BY PENNSYLVANIA WATER & POWER CO.

NO. TURBINE INSPECTION (1)	Lig.Vitae bearings & liners? (4) N. S. E. W.
Cross-head pin?	Water strainers?
Eye bushing?	Turbine guide bearings
Conn. Rod pin?	
Eye bushing?	Gen.bearings-lower? Upper? Gen.brake jacks?
Reach Rod pins: N.E. S.E. N.W. S.W.	Brake shoes?
Link Pins? Oper. rings?	Loose bolts? Castings?
Vane? Headgate condition?	Stock in shoes?
Lifting mech?	Any leak in concrete?
Casting condition?	Gov. gear drive coupling and shaft?
Broken bolts? Loose Nuts?	REMARKS
Grease Piping Conditions	
Loose hangers? All pins and bearings getting grease?	
Fulcrum pins charged? (2)	Wear on supporting segment (3) liners?
Oper. shaft pedestal and step bearings condition?	Ladder on shaft?
Is pedestal bearing loose?	Oper. ring clearance at 50% gate: Top.....N. E. S. W. Bottom..N. E. S. W.
Sole plate loose? Bolts broken?	Fulcrum pins condition?
Pedestal bearing boxes?	Vanes move freely on fulcrum pins?
Upper journal conditions	Vanes close O.K.?
Lost motion in pedestal bearing?	Full gate in inches?
Greasing? Amount of wear on step-bearings?	Reach rod eyes or jam nuts loose?
Oper. shaft, rivets and bolts?	Wear on cross head and guide?
Wear on vane discs?	Oper. mech. move freely?
Vane discs worn into distr?	Full piston stroke (inches)?
Clearance between vanes and bottom distr?	Runner condition?
Clearance between top oper. ring and vanes at full gate?	Clearance at bottom rings: Top.....N. E. S. W. Bottom..N. E. S. W.

TABLE II. TYPICAL INSPECTION REPORT OF CONSUMERS POWER CO.

VERTICAL TURBINE, GENERATOR AND EQUIPMENT

Turbine No.
Make
Head Gate
Head Gate Hoist
Penstock
Scroll Case Drain Valve
Cover Plate Drain
Is Cover Plate Clean?
Guide Vane Opening
Guide Vane Closing
General Appearances: Runner
" " Guide Vanes
" " Scroll Case
Lighting over Cover Plate
Vacuum on Draft Tube
Runner Clearance: Cover Plate Discharge Ring
Flow of River Flow of River

(Position of Rotor Leads should be down stream)

Governor:
Make and Type
Operation
Fly Ball Mechanism
Pilot Valve
Main Regulating Valve
Floating Levers
Dashpot and
Compensating Gear
Oil Valves
Load Limiting Device
Connecting Rod Bearings
Fly Balls to Governor Stand
Synchronizing Motor and Control
Gate Indicator

Hand Control - Oil Pressure Type Handwheel type
Valves
Compensating Lever Pins Valves
Pump
Operation
Handwheel and Mechanism

Governor Oil System
Oil - Quantity
Condition
Pressure Carried
Vacuum
Pump
Relief Valve
Pump Motor
Winding Is Motor Clean?
Bearings Air Cap
Compensator or Switch
Belt
Pulleys Air Compressor
Piping
Receiving Tank to Pump
Governor to Regulating Cylinders
Hand Control to Regulating Cylinders
Receiving Tank and Screen
Pressure Tank to Governor
To Hand Control Stand
Water Cooling Coil and Valves

Regulating Mechanism
Regulating Cylinder
Shifting Ring
Guide Vane Links and Pins
Eccentric Pins
Vane Stems
Pistons Rods Pins
Shift Ring Grease Cups
Guide Vane Link Grease Cups
Eccentric Pin " "
Valve Stem " "

Bearings
Thrust Bearing
Maximum Operating Temperature
Since last Inspection
Oil Gage
Cooling Coil
Cooling Coil Piping and Valves
Water Supply
Oil Piping
Thermometer
Oil Flow Indicator and Alarm
Water Flow Indicator

Upper Generator Steady Bearing
Bearing Oil Flow Indicator
Oil Pan Oil Piping and Valves

Sealing devices and packing must also have attention, especially if packing requires lubrication. If it is found that the shaft is scored, the packing is either not properly installed or lubricated. Flax and cotton packings, properly lubricated, have often been used. Long fibre asbestos packing, impregnated with graphite lubricant, has proved successful in some plants; others have employed hemp packing boiled in tallow at suitable intervals. Granulated wood and metal packing is coming into frequent use. Plastic metallic, three-piece

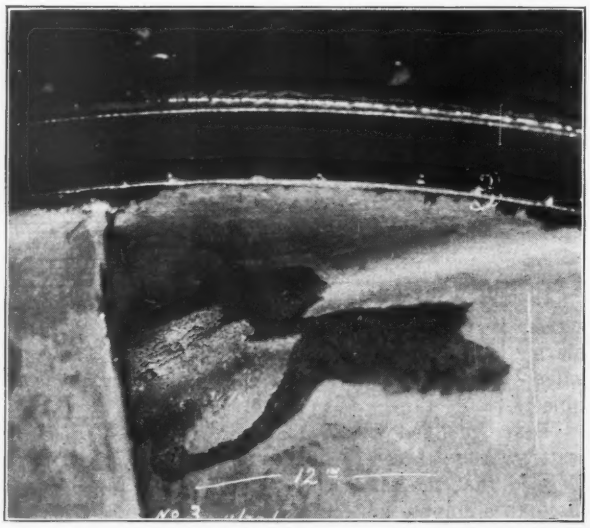


FIG. 2. RUNNER WELDED TO REDUCE PITTING AND BUILD UP PITTED AREA. PITTING CONTINUED AROUND THE WELD.

diagonal and c-ring packing have also been used to some extent.

While cleanliness is of importance in any generating station, it is especially so with respect to the governors of hydraulic turbines. Governor apparatus should be wiped with cloth once a day. Oil pumps, whether of motor-driven or belt-driven type, should be watched for noise, bearing temperatures and joint leakage. Pressure piping of oil-pressure governors should be kept tight and should be blocked if it tends to vibrate. Belts driving flyballs should be kept at the proper tension and arranged so that the pilot valve will not jump when the belt lacing passes over the pulleys. Leakage from stuffing-boxes of regulating cylinders on the cover plate should be prevented. Pilot valves should be frequently inspected for wear and sticking; flyballs should be lubricated daily; dash-pot oil should usually be changed yearly; scum should not be allowed to form around pilot-valve ports, if a solution with water is used instead of oil. Belts on synchronizing motors should be watched for tension.

Complete instructions for care of water-wheel-driven generators are beyond the scope of this article. The principal precautions to be taken, says W. W. Tefft, are as follows: the generator should be cleaned of dust once a week, using preferably an air jet or vacuum cleaner, to prevent clogging of windings and shutting off of ventilation; a leaky thrust or steady bearing should be repaired as soon as possible, to prevent oil from getting on the generator windings to cake with dirt and to break down the insulation; thrust bearing temperatures should be recorded hourly and some form of alarm should be provided to signal stoppage of flow of the bearing cooling water.

When inspection shows pitting of the runner, the procedure will vary according to the operating conditions of the station. The entire process of pitting is so intimately connected with the water conditions, setting and other factors of design, that elimination of the cause of pitting is usually beyond the control of the operator. Considerable data on the causes of pitting have been accumulated by the Hydraulic Power Committee of the N. E. L. A.

Pitting on existing runners may often be minimized by building up the affected areas by the electric arc welding process. The oxy-acetylene welding process may be used if care is taken to get uniform heat and prevent shrinkage cracks but the electric arc has been used with most success.

By using the proper electrodes, large cast-iron runners have been welded in place, depositing the metal in an overhead position. In the usual procedure, the

FIG. 3. ANOTHER PITTED RUNNER IN SAME STATION AS THAT SHOWN IN FIG. 2. PITTING CONTINUED AROUND WELD AND AROUND HOLE DRILLED TO STOP IT

pitted areas are first chipped out, taking care to leave square edges; then the parent metal is drilled and tapped for ½-in. studs spaced about 3 in. apart; finally, the area is built up to the original bucket contour by depositing a metal that resists pitting better than the parent metal. In some cases, successive layers of the metal are peened, as they are deposited, to relieve temperature stresses. In other cases, the area is built up to contour and then ground to a smooth finish. While the smooth finish in itself is not essential, the surface must be so finished that irregular contours are eliminated and so that there will not be any chance of the water being deflected in passing over the weld.

Some companies have used in the bottom of the weld a metal that bonds well with the parent metal, rather than one that resists pitting, covering this in turn with a metal designed primarily to resist pitting.

Most experience has been that steel with a high percentage of carbon and manganese offers more resistance to pitting than pure iron. Various kinds of cements, paints and metal spraying processes have been tried for building up pitting, but with scant success.

Type metal has been used but not long enough to warrant conclusions and the success of rubber for this work is also unknown.

Turbine runners have been supplied with pitting plates at the portions of the runner where pitting might occur if the draft head becomes excessive. Application of such plates to runners that have begun to pit has also been known to stop or reduce the pitting. In many cases, holes have been drilled through the vanes or blades with the idea of relieving the vacuum on the under side. There have been objections to this on the ground that the loss in turbine efficiency is too great; little definite information is available on this point, however.

Figure 2 shows a portion of a runner that was welded to reduce pitting and build up the pitted area. The metal was deposited on studs by arc welding in the manner indicated above and the weld is clearly shown by the light colored part. Despite this precaution, pitting continued around the weld, as can be plainly seen. On another runner, Fig. 3, which was welded and still continued to pit, a 1-in. hole was drilled to stop pitting but did not seem to be effective, as the pitting continued around the hole and around the weld. It is to be noted, in both these cases, that the welded part itself did not pit seriously. These runners were part of an installation of three units but the third runner, operating under the same water conditions and head, with the same type of draft tube, did not pit as badly as the other two. Furthermore, several similar runners in another plant on the same stream under practically the same head but with a different type of draft tube, did not pit at all.

Thus it is seen that while steps may be taken to repair pitted runners, with more or less success, this procedure does not necessarily eliminate the causes of pitting.

Effects of Pitting, Wear and Vibration

"Pitting of the runner," says Tefft, "is not believed to have a serious effect on the efficiency of the unit until the pitted area becomes so extensive and the pitting so deep that the shape of the water passage is materially changed; it is usually found that before this occurs, the strength of the runner has been seriously affected and it is desirable to renew the runner entirely or build up the pitted area."

Water wheels have been known to run 20 yr. without appreciable wear and without serious change in efficiency. Amount of this wear depends in some ways on the clearance spaces around the runner, especially on high-head turbines of low specific speed. With 0.020 clearance, leakage through this space, it is stated, may affect efficiency from 1 to 3 per cent. If the clearance increases 3 or 4 times, caused by dirt in the water, the loss in efficiency may be from 3 to 10 per cent. It has been recommended that a definite maximum clearance should be set as a limit, at which wearing rings are to be renewed, especially on turbines operating at heads above 250 ft.

Clearance between guide vane ends and guide case on high head turbines should be watched because sand or silt in the water may cause rapid wear and high leakage when the unit is shut down. To prevent this wear, a tight valve of some sort might be provided to be closed when the unit is shut down.

Vibrations in water wheels, says the N. E. L. A. Hydraulic Power Committee, may in general be classified as periodic, non-periodic and mechanical unbalance vibrations. Periodic vibrations may be caused by pressure reactions, close clearances and high specific speeds, runner and guide vane combinations. These may weaken the penstock and other parts of the structure and may contribute to pitting as well as loss of efficiency. Non-periodic vibrations may be caused by draft tube surges and air surges (sometimes arising from obstructed tailwater passages) or by extreme variations in head. They may cause penstock breathing, shocks or pounding and bearing trouble. Vibration due to mechanical unbalance may be caused by blocking of the runner. This type of unbalance is usually apparent once a revolution and has not the sharp impact characteristics of the other two types. It is usually so apparent that immediate shutdown is necessary.

TABLE III. ANALYSIS OF CAUSES OF OUTAGE OF HYDRAULIC TURBINE GENERATORS IN PER CENT OF TOTAL OUTAGE TIME

	Propeller Type	Impulse Type	Horizontal Reaction Type	Vertical Reaction Type	All Reaction Type	All Units
Number of units included	4	12	6	64*	70*	86*
General Hydraulic Causes:						
Ice or trash	2.23	0.46	0.00	1.04	0.88	1.08
Floods	0.00	0.00	0.00	0.00	0.00	0.90
Penstock or canal	0.00	21.63	48.64	3.70	10.37	9.75
Headgates or intakes	0.03	0.00	0.83	1.84	1.69	1.21
Other general hydraulic	0.00	0.06	3.61	14.93	13.25	9.43
Total general hydraulic	2.25	22.14	53.08	21.51	26.20	21.46
Water Wheels and Auxiliaries						
Runner	0.00	1.16	3.71	21.50	18.55	13.53
Turbine shut-off valve	0.00	8.61	1.23	4.96	4.41	4.08
Turbine gates or needle nozzle	0.00	6.36	0.86	5.52	4.83	4.13
Guide bearings or main bearings	0.00	0.25	1.24	4.90	4.36	3.13
Thrust bearings	0.00	0.00	0.22	0.06	0.08	0.06
Governor and governor system	89.58	2.52	2.26	2.37	2.36	18.03
Pressure regulator or deflectors	0.00	3.64	0.44	0.00	0.07	0.45
Draft tube	0.00	0.42	0.05	1.26	1.08	0.82
Lubricating system	0.00	0.00	0.56	0.00	0.16	0.11
Vibration	0.00	0.00	0.06	0.32	0.28	0.20
Seal rings	0.00	0.00	7.44	2.56	3.29	2.34
Inspection	5.55	4.33	13.10	1.31	3.06	3.64
General overhauling and replacement	0.00	7.33	0.00	10.13	8.62	6.94
Other causes	0.08	1.26	0.34	2.72	2.37	1.43
Total water wheel	95.19	35.95	31.51	57.70	53.81	59.28
Generator and Appurtenances:						
Vibration	0.00	0.08	0.00	0.06	0.05	0.04
Lubrication or oil system	0.00	1.66	0.52	8.96	7.70	5.66
Rotor or field	0.08	18.82	4.50	1.12	1.62	3.23
Armature iron or windings	0.56	5.23	2.11	1.85	1.88	2.01
Exciter and rheostats	0.40	0.62	1.85	1.03	1.15	0.96
Ventilation system	0.00	0.00	0.00	3.95	3.37	2.39
Cleaning	0.00	11.53	4.69	1.65	2.10	2.76
Inspection	0.00	3.99	0.54	0.38	0.41	0.73
Other causes	1.52	0.00	1.20	1.80	1.71	1.49
Total generator	2.56	41.91	15.40	20.79	19.99	19.27
Total—all causes	100.00	100.00	100.00	100.00	100.00	100.00
Total outage time in per cent of total time	11.28	2.30	4.43	3.03	3.15	3.41

Table III shows an analysis of outage of a number of hydraulic turbines, made by the Hydraulic Power Committee of the N. E. L. A. These data are for 1926 and include, for the first time, information on four propeller type runners, installed in 1924. Each of these developed 30,000 hp. at 120 r.p.m. under 60-ft. head.

The table shows that, during 1926, the propeller type group, the vertical reaction type group, all reaction units and the group of all units experienced greatest percentages of outage time from causes related to water wheels and their auxiliaries. For the impulse type group, generators and appurtenances caused highest outages. For the horizontal reaction group, general hydraulic troubles caused high outages.

Principal single causes of outage in the class of water wheels and auxiliaries shifted in this analysis to the governor and governor system, with the runner in second place. For the group of all units, none of the causes related to generators is of sufficient magnitude to be outstanding; high figures in individual classes result mainly from accidental high records of single units.

Faulty Piping Impairs Injection Pump Action

INCLUDED IN the prime-movers of the plant in which I am employed, are two 3-cylinder, vertical, solid-injection Diesel engines. One of these engines, after being overhauled, would run satisfactorily for an hour or so and then the center cylinder would miss, which meant that the fuel-pump delivering oil to that cylinder was not functioning properly. The pump was then worked by hand by means of the priming-lever, until the pump caught the oil again, then it would work all right for another hour or so and again lose its oil. The pump suction and discharge valves, overflow valve and spray valves, were in perfect condition. The fuel oil was free

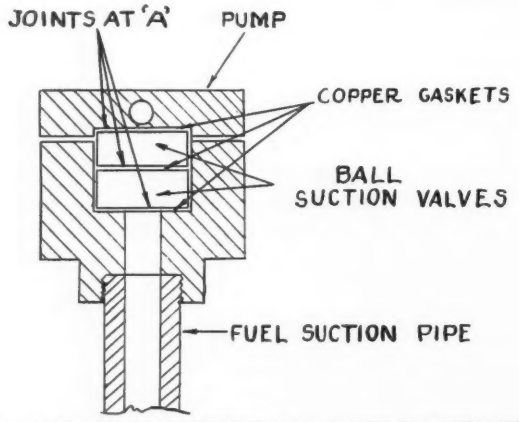


FIG. 1. AIR LEAKS OCCURRING AT A DUE TO MISALINEMENT OF PIPING, BREAK SUCTION OF PUMP

from water and dirt, and there was no obstruction in the fuel oil suction pipe or header.

The fault, however, was in the fuel oil suction header. One of the half-unions had been made up too far, with the result that when the unions were tightened the center of the suction pipes to the pumps were shortened causing the joints at A, Fig. 1, to be at a slight angle when they were tightened and making a joint which was not air tight. On the suction strokes of the pump, a little air was drawn in at A and this air built up, until the pump became air-bound.

When the pump was worked by hand, it was given a longer stroke and the air was expelled through the overflow valve at B, after which the pump operated all right until the air-lock formed again. The trouble was remedied by breaking all the unions on the suction header, tightening up the suction pipes square to the pump at A, and then unscrewing the half union which was open until the union butted. The end of the unscrewed union was then sealed to the pipe with solder.

We were also troubled with fuel pump rollers seizing to the pins in the fuel pump plunger head. The

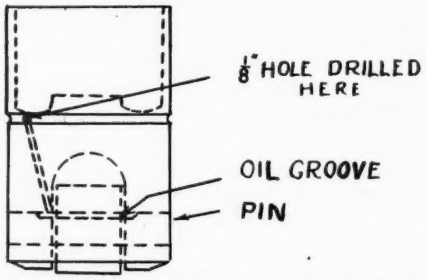


FIG. 2. HOLE THROUGH PUMP PLUNGER TO OIL GROOVE PERMITS LUBRICANT TO SERVE PIN IN PLUNGER HEAD

cam running in oil was supposed to throw up enough oil to lubricate these pins and rollers, but, when the oil became thinned with fuel oil from leaks, these rollers seized to the pins, causing damage to the nose of the cam. This trouble was eliminated by leading a ⅛-in. pipe to the pump bracket from a drip lubricator, and drilling a ⅛-in. hole through the pump plunger head to meet the oil groove in the pin as shown in Fig. 2.

Newark, N. J. GEORGE BOGIE.

Handy Rule for Determining Belt Tension

HERE IS a handy rule for determining the tension in a belt that is slack enough so that the sag can be measured. The tension can be computed easily—without the necessity of expensive or complicated apparatus. For leather belts, proceed as follows:

Multiply the width of the belt in inches by its thickness in inches; then multiply by 0.43; we will call the answer "P." Now, multiply "P" by the sag of the belt in feet; we will call the answer "A." Next, multiply "P" by the square of the center to center distance between pulleys in feet; multiply by 0.125; divide by the sag of the belt in feet; we will call the answer "B." Lastly, add "A" and "B" and the result is the exact total tension in the belt in pounds.

No matter what the sag is, if it is only ½ in., or any

sag within reason, the foregoing rule will apply. It may sound cumbersome, but its use is simple.

For example, let us take a case where the distance between pulleys is 20 ft.; the sag is 6 in., or equal to 0.5 ft.; the belt is 6 in. wide and ¼ in. thick. What is the total tension?

Applying the above method, we get:

$$P = 6 \times \tfrac{1}{4} \times 0.43 = 0.645$$

$$A = 0.645 \times 0.5 = 0.322$$

$$B = \frac{0.645 \times 20^2 \times 0.125}{0.5} = 64.5$$

$$0.322 + 64.5 = 64.82 \text{ lb.} = \text{total tension.}$$

Newark, N. J. W. F. SCHAPHORST.

Wear on Pin Wrecks Engine

SOME TIME AGO, an engine that I am operating broke down. It is a 20 by 24-in. four-valve, nonreleasing Corliss, operating at 204 r.p.m. and direct connected to a 3-wire, 3-phase, 2300-v., 250-kw. alternator, with a 25-kw. exciter belt-driven from a pulley on the outboard bearing end of the engine shaft.

The cause of this wreck was wear of the pin and bushing of the inertia governor shown at Fig. 1. These parts wore until the wrist plate had a crosswise motion on its support, giving a wobbling motion to the eccentric and twisting the eccentric rod at every revolution until it finally broke off at B. The break permitted the eccentric strap to swing freely around the eccentric.

The engine has a double eccentric and is supplied with a cast-iron drip pan under the eccentrics and a sheet-iron case over them as shown in Fig. 2. These parts were stripped off, while the exhaust eccentric rod was bent 6 in. out of line and in three directions. I was unlucky enough to have my foot broken by having it hit by one of the flying pieces.

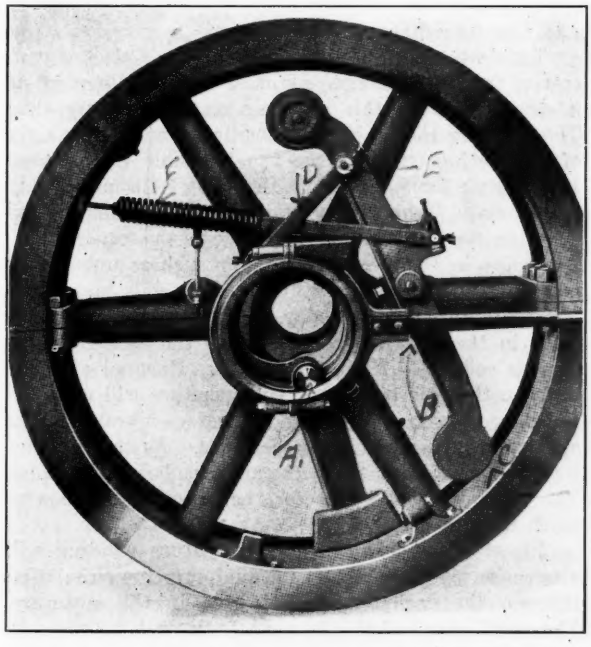


FIG. 1. INERTIA SHAFT GOVERNOR, WHOSE PIN CAUSED TROUBLE DUE TO WEAR

After the broken rod was welded, the bent one was straightened in our shop as shown in Fig. 3. Heavy iron plates were laid across the platen of a drill press, the ends being placed on wooden blocks as shown and the third wooden block, which was supplied with a handle, was used between the spindle of the drill press and the top of the rod to be straightened. The rod was heated

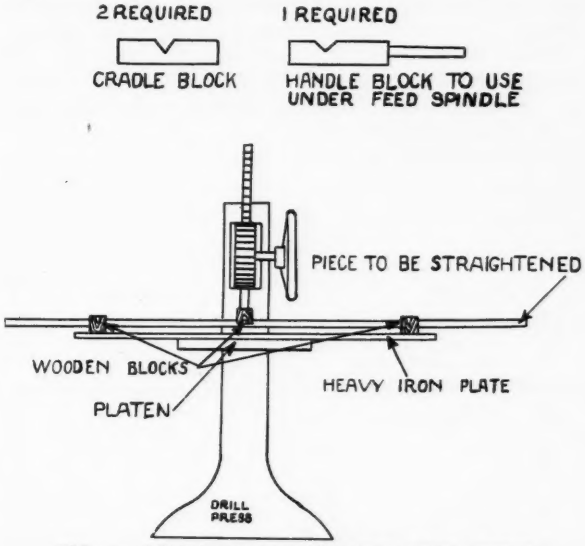


FIG. 3. SKETCH SHOWING HOW RODS WERE STRAIGHTENED IN DRILL PRESS

in a forge, laid on the cradle blocks and pressure applied at the middle by running the spindle down by hand.

By adjusting the position of the rod and cradle blocks, any kind of kink or bend can be removed from a pipe or rod. The particular rods in question were made of 1½-in. pipe, flattened at one end to fasten to the eccentric straps, with a solid piece welded into the wristplate end as shown in Fig. 4. The pipe was tapered at both ends to the size of the threads.

About two months after the first wreck, the exhaust eccentric broke off at the point shown in Fig. 4. A new butt was welded in and threaded. Card A, Fig. 5, shows how the average card looked before the wreck. Card B shows what was going on after the wreck occurred; card C, after a few adjustments were made

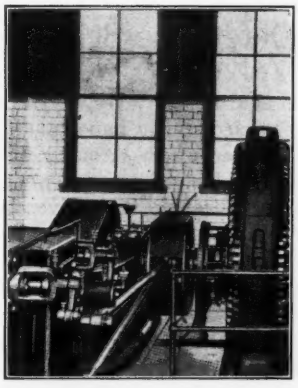


FIG. 2. ENGINE THAT WAS WRECKED SHOWING SHEET IRON GUARDS OVER ECCENTRICS

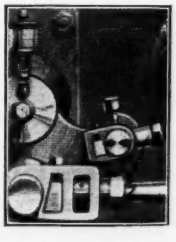


FIG. 4. EXHAUST ECCENTRIC ROD SHOWING POINT WHERE BREAK OCCURRED

and card D, after a little more load was applied. Card E looks fairly good but it is deceiving. The indicator spring worked loose on the connection to the indicator reducing motion, making the flat steam lines to points of cutoff as shown. Otherwise all cards ever taken from this engine had the appearance of card D.

At the time of the first wreck, the arm with the eccentric was taken off and the pin A, Fig. 1 and the bushing were found to have a combined wear amounting to 5/16 in. The pin was worn flat on one side. It was trued up and a new bushing made. A wooden wedge was driven in at C between the end of the governor arm and the flywheel rim, in order to relieve the strain so that the pins E on the end of link D could be removed without reducing the tension on the spring F. The wreck occurred at 9:15 a. m. and the repairs, except

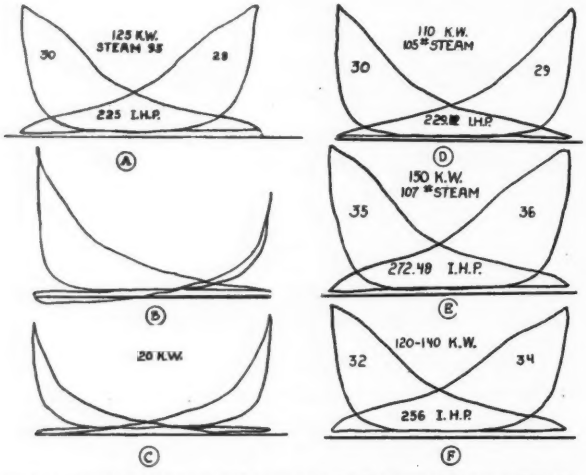


FIG. 5. INDICATOR CARDS SHOW THE EFFECT OF BREAKAGE AND OF CHANGES MADE ON ENGINE

A. Average card taken before wreck.
B. Taken after wreck occurred.
C. Card, after a few adjustments were made.
D. Result of adding a little more load.
E. Effect of incorrect indicator action.
F. A good appearing card.

the welding of the eccentric rod which was sent out for repairs, were completed and the engine was in service by 10:00 p. m.

Minneapolis, Minn. FRED S. RUTLEDGE.

Qualities Which Determine Selection of Valves

WHEN SOME ENGINEERS require new valves, they think only of the type of valve needed; other important features are, however, often overlooked. Among these features are kind of metal of which the valve is made, kind of fluid to be passed through the valve, and whether or not the fluid contains an acid or other chemical which may be destructive to iron but harmless to brass or some other valve metal. Many different metal combinations are now used in valve castings.

Next we may consider weight. Experienced buyers are aware that similar types of valves made by different manufacturers vary considerably in weight. Price and other things being equal, the heavier valve would seem to be the better purchase; however, the nature and distribution of the metal used must also be considered to see whether the added material has been placed where the heavier stresses are applied.

When the valve purchased is of the safety, reducing or check types, preference should be given, other things being equal, to one in which the space between the disc and valve seat is greatest when open. Valves that open only a small amount or self-opening valves where the disc and seat are always quite close together, wear and leak sooner than valves that open wide, due probably to the scoring effect of rapidly moving steam or liquid.

Toronto, Canada. JAMES E. NOBLE.

Vibration in Steam Turbines

VIBRATION is a common trouble in steam turbines, often developing during operation without apparent reason. Some reasons for vibration are: stripping of some of the rotor blades, collection of deposit on the blades and in the passageways, fault of some kind in the coupling between the turbines and generator or fault in the generator itself. Unsteady admission of steam through the action of the governor may also cause vibration.

Stripping of some of the rotor blades is not unusual. This causes the rotor to become unbalanced. The usual cause of blade stripping is slugs of water and solid matter in the steam. The collection of deposit on the blades may also cause vibration. When steam contains solid impurities, they will be carried with the steam and act as a sand blast on the first blades but as they pass through the turbine they will collect on the blades in the latter stages. This will increase the weight on the blades and may unbalance the rotor.

If the boiler plant is poorly operated, the steam may carry over considerable muddy impurities which will collect in the turbine. The remedy for this is to operate the boiler carefully, avoid priming and keep the percentage of solids in the boiler water as low as possible. Passing the water through a steam purifier before it enters the turbine will free the steam of any slugs of water or solid impurities.

Turbines are usually connected to their electric generators through a flexible coupling and misalinement or misadjustment of this coupling may cause vibration. The coupling should be periodically examined for signs of hammering which is the usual trouble experienced. Hammering damages the teeth and conditions quickly grow worse. Truing the teeth and making other needed adjustments will cure vibration due to this cause.

Faults in the electric generator such as unbalanced magnetic pull from the different field coils may cause serious vibration. This may be due to some electrical fault in the windings which causes the flux from the various coils to differ considerably. Unequal air gaps between the pole pieces and the armature will cause an unbalanced magnetic pull and therefore vibration. This occurs through wear in the bearings. As the bearings wear, the rotor lowers and the air gaps become unequal. The bearings should therefore be taken up as soon as much wear occurs.

Electrical unbalance in the armature winding will also cause vibration due to unequal currents circulating through the various parallel paths in the armature. The usual cause of this is some fault such as grounds, short circuits or bad joints in the wings.

Brentford, England. W. E. WARNER.

Washing a Horizontal Tubular Boiler

IN MANY CASES, steam boilers are not washed out as often as they should be, owing to lack of proper facilities. When there are two or more boilers, the operation is comparatively easy because hot water under pressure can be obtained from one boiler which remains under steam. It is when the isolated, single boiler must be washed that the engineer is hard put, not only for wash water but also for water to refill the boiler after it has been cleaned out.

For the isolated boiler, where there is no city water service, a tank should be installed high enough above the boiler to furnish sufficient working pressure; or a donkey boiler should be set up for use when the large boiler is closed down. Of the two expedients, the donkey boiler is the better because an injector may then be employed to force a stream of heated water into the boiler. Boiler washers, which operate in a manner similar to injectors and which are on the market, are excellent devices for this purpose.

When preparing a boiler for washing, the necessary operations differ according as the boiler is to be washed with hot or cold water. If the former is to be used, washing may commence as soon as the manhole plate has been removed. The boiler, however, should not be blown down under pressure; the water should be discharged only after the steam pressure has dropped to almost zero. When cold wash-water must be used, the boiler should be cooled to such a temperature that water will not flash into steam when it hits the shell plates or tubes.

When the wash-water does not have force enough to remove the dirt from the shell and tubes so that the latter must first be scraped, it is necessary first to cool the boiler enough to permit a man to work inside with a scraper and brush. In washing a boiler, the precaution should be taken to let the washwater and dirt run out through a handhole under the tubes. If it should be necessary to discharge the water and dirt through the blowoff pipe, care should be taken to see that the blowoff pipe does not become choked with dirt and sludge.

Indianapolis, Ind. JAMES F. HOBART.

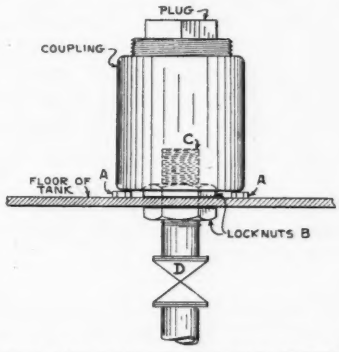
Emergency Siphon Drains Tank

CLEANING LARGE WATER storage tanks is usually part of an engineer's duty. Sometimes the draining pipe is installed as shown in the sketch with the end of the pipe several inches above the bottom of the tank as shown at C. When this is the case, it would be a tedious and costly job to dip out the water left so as to permit the tank to be cleaned out. This water is often removed by placing a large funnel in pipe C and dipping and emptying the water into it.

To save all this labor, take an iron pipe coupling one or two sizes larger than C, oil or paint the threads of a pipe plug of the same size as the coupling and screw it in as tight as possible with the hands. Place three or four ½-in. nuts AA on the bottom of the tank and set the coupling and plug over C and lock nut B with the edge of the coupling resting on the nuts. This can be done when there is still about a foot of water in the tank and while the drain pipe valve D, is open as the water flows out through C. A partial vacuum will be set up under the coupling and siphon action will be started which will continue until all of the water in the tank flows out until the level is lowered to the top of the nuts AA. This small amount of water then can be mopped up.

If the drain pipe runs direct to the sewer or outside and has no connections with any fixtures, a couple of men with brooms should enter the tank when there is still a couple of feet of water in it, and, using the brooms freely, should stir up the dirt deposited on the bottom. As the water continues to flow out, much of this dirt will then be carried out along with it.

This sweeping cannot be done if any pipes supplying wash basins or other pipe having valves or cocks



PIPE COUPLING AND PLUG FORM CAP OVER DRAIN AND CAUSE PARTIAL VACUUM TO BE SET UP RESULTING IN SIPHON ACTION

attached, are joined into the drain pipe, because the dirt might stop up the cocks or valves or collect under the valve discs and cause leakage.

Toronto, Can. JAMES ELLETHORN.

Transmission Capacity of Angular and Vertical Belts

RULES FOR CALCULATING the horsepower transmitted by belting are usually based upon horizontal belts. In order to find the capacity of a vertical or inclined belt whose angle with the horizontal is greater than 40 deg., subtract the angle of inclination from 140. The result will be the percentage of capacity as compared with a horizontal belt of the same size.

For example: if the angle of inclination is 45 deg., we should have 140 — 45 = 95 per cent of the horizontal capacity. We should, therefore, deduct 5 per cent from the capacity of a similar belt running horizontally. Applied to a vertical belt, 55 per cent would be deducted. This seems to be considerable but for continuous service for most drives, it is recommended as safe.

Newark, N. J. N. G. NEAR.

AT THE LAST SESSION of the Massachusetts Legislature a bill was passed, according to a recent report, providing that all municipal plants must include in their production costs the items of interest on invested capital and reasonable depreciation. The object of the bill, it is stated, is to reduce to the same basis the calculation of production costs of both municipally owned plants and privately owned utilities.

Questions and Answers

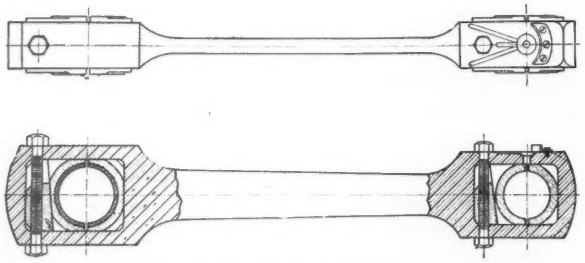
Connecting Rod Adjustment

WHAT EFFECT WILL there be on the clearance of a steam engine cylinder, if the crankpin and crosshead pin boxes are tightened up?

2. Where should the shims be placed in relation to the brasses on a connecting rod as illustrated, if the cylinder has more clearance on the crank end than on the head end, the piston rod being keyed in?

3. In what position is it best to place the crank on a horizontal engine when tightening up the wedge bolt on the crankpin? W. F. W.

A. If there is no wear on the two boxes or if there is equal amount of wear on both, there would be no



CHANGE IN CENTER TO CENTER DISTANCE OF CONNECTING ROD PINS DETERMINES CHANGE IN CYLINDER CLEARANCE

change at all in the clearance, since the center to center distance between pins remains the same and the compression in the cylinder keeps the pins against the inner brasses at the end of compression.

2. The best way to analyze the effect of change of location of shims on the cylinder clearance is to note the effect of such change on the center to center distance of the pins. If this center to center distance is increased, the clearance space on the head end will be decreased and the compression pressure will be increased. At the same time, since the piston is moved by this means away from the crosshead, the clearance space on the crank end will be increased and the compression pressure correspondingly decreased. Decreasing the center to center distance will have an opposite effect. To increase the center to center distance, one or more shims should be taken from the outer side of the box, between the outer brass and adjusting block and placed between the inner brass and connecting rod.

3. If mere tightening of wedge bolts is required, the position most convenient for doing this tightening would be the one most desirable, as the bolts will easily move the rod and piston unless they are very heavy. If these parts are heavy, the engine may be turned over until the pin bears upon the brass opposite to the one that needs to be drawn up. In this case, tightening up the wedge bolt merely moves the brass which is loose. If shims are to be changed, it is best to stop the engine at or near the head end center then loosen the wedge block on the crankpin and turn the engine over a little toward the head end so as to relieve the pressure on the two brasses. The shims may then be easily changed.

Voltage Drop in Alternator

WE HAVE A turbine-generator which formerly had a 600-kw., 310-v., 967.8-amp. per terminal, 3-phase generator but which now is arranged as 440-v., 2-phase, 60-cycle. The power factor is 80 to 85 per cent and speed 3600 r.p.m. It has motor-driven excitation from a 25-hp. induction motor, driving a 115-v., 152-amp., 17.5-kw., 1200-r.p.m. generator.

This machine runs at a uniform speed at all times. With 440 v., 400 amp. and 250 kw., a 10-hp. or larger motor hits the line through a compensator and the voltage drops to 250 or 300 v. and remains there until it is raised by the rheostat. It will not build up its voltage without help. There are some 150 induction motors on the line ranging from ¼ to 75 hp. and two 150-hp. motors of the slip-ring type. What is the cause of this drop and how can it be remedied? D. R. K.

A. From your description, we assume that you have had this machine reconnected so as to change it from a 310-volt, 3-phase machine to a 440-volt, 2-phase machine. While the voltage regulation on an alternating-current machine is quite broad, it is extremely unusual to encounter a voltage drop of from 440 volts to 250 or 300 volts with the addition of less than 10 per cent load. Alternating-current machines sometimes have as much as 30 per cent variation in voltage between zero load and full load but this represents practically the limit of such voltage change.

We assume also that you wish to maintain constant or nearly constant voltage under varying load conditions without resorting to hand regulation. This, in our opinion, cannot be accomplished without the use of some form of voltage regulator. In a direct-current machine, by means of a compound winding, any desired regulation characteristic can be secured; in fact, a machine that is over-compounded will actually show a voltage increase with an increase in load.

With an alternating-current machine, however, the voltage builds up from zero to maximum value and then decreases as the load is still further increased. It is this broad regulation characteristic of the alternating-current machine which we believe is responsible for your difficulties. The effect may be accumulative.

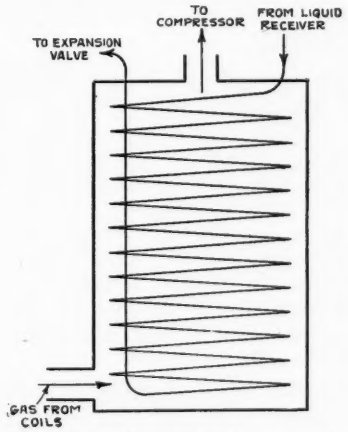
You state that your turbine does not drop in speed. There may, however, be a slight drop in speed unnoticeable to the eye when the additional load is added which, in turn, results in a slight decrease in voltage of the generator. Since the generator is excited by an induc-

tion-motor-driven exciter, this voltage drop will result in a slight decrease in speed of the exciter which reduces the excitation voltage somewhat. This, in turn, effects a still further drop in voltage of your generator. This, we believe, is what occurs in your machine and, to check it up, we suggest that you take very accurate readings of all your meters, at the same time measuring the speed of the turbine with a sensitive tachometer. Unless all these readings are taken simultaneously, the effect, which we describe here, will probably not be noticeable.

Suction Trap Improves Regulation in Refrigerating Plant

WE HAVE 23 expansion valves in our refrigeration plant, which have to be so nearly closed to be regulated that our margin of range is insufficient, thereby requiring considerable attention.

We have been thinking that, if we installed a master or regulating valve on the liquid line between the receiver and the expansion valves near the freezers that



DIAGRAMMATIC REPRESENTATION OF SUCTION TRAP CONNECTIONS TO IMPROVE REFRIGERATING PLANT REGULATION

it would overcome this trouble. We run from 150 to 260 lb. condenser pressure and about 5 to 10 lb. suction pressure and by reducing the pressure in the liquid line, we think that we could open our expansion valves more and overcome this trouble by making a wider range for regulating. Our liquid line is 1¼ in.; our compressor is a 75-t. ammonia machine. A. A. A.

A. In the first place, your plant is supplied with too many expansion valves for a 75-t. ammonia machine.

You may, however, eliminate your trouble by putting a suction trap, such as shown in the sketch, in the suction line just before the ammonia gas enters the compressor. An internal cooling coil should be placed in the trap as shown.

If this is done, any entrained liquid coming back from the cooler will drop in the trap and in turn cool the liquid in the coil.

Installation of this suction trap as suggested will not only prevent the surging back of liquid to the compressor but, by avoiding the passing of liquid to the compressor and by the heat interchange which is accomplished, the efficiency of the plant will be raised.

Shutting Off Steam at Night

WHAT WOULD be the approximate saving in coal if the steam were shut off every night for 12 hr. in the following: One hundred feet of covered 5-in. pipe, 300 ft. of covered 10-in. pipe, 600 ft. of covered 6-in. pipe and a 14 and 8½ by 15-in. boiler feed pump. The steam pressure is 100 lb. and the outside temperature is about 90 deg. The pipe is covered about 1½ in. thick with 80 per cent magnesia. T. B. B.

A. You should consider whether or not it is necessary to keep these steam lines hot for emergencies or whether the amount of steam consumed in warming them up in the morning would more than offset the amount saved during the night.

In most cases, however, this would not be true.

Now, assuming a covering 1½ in. thick of 80 per cent magnesia on each of the steam lines which are operated at 100 lb. pressure, we can figure the heat loss through the insulation. We have assumed that the total area of the insulation would be the length of the pipe times the circumference of the outside of the covering. The covering area will then be:

$3.14 \times [(8.56 \div 12) \times 100 + (13.75 \div 12) \times 300 + (9.62 \div 12) \times 600]$ = approximately 2800 sq. ft.

According to the Guide of the A.S.H. & V.E., the heat loss through insulation of this type would be 70 B.t.u. per sq. ft. per hour, or a total of 196,000 B.t.u. per hour for the three lines of 5 in., 10 in. and 6 in. pipe. Since a pound of steam at 100 lb. will give up about 872 B.t.u. in condensing to water at the same pressure, you will have to supply about 225 lb. of steam per hour to make up for the radiation losses from these lines. If you assumed that your boiler evaporated 6 lb. of steam per lb. of coal, that would mean about 37.5 lb. of coal an hr., or 450 lb. for 12 hr. In the course of a year, this would represent about 82 t. of coal. On the other hand, it would be possible, by adding more insulation to the pipe lines, to prevent a great deal of this loss, but the cost for the additional insulation might be more than the amount of coal that would be saved by putting it on.

Next let us assume that the pump operates at 10 r.p.m. and that it has a 3-in. piston rod. Then the 14 by 15-in. steam cylinder will have a displacement of 13.25 cu. ft. per min. on the head end, and 12.6 cu. ft. on the crank end. These capacities are figured as follows:

$0.785\ (14 \div 12)^2 \times (15 \div 12) \times 10 = 13.25$ c.f.m. piston displacement, head end.

The area of the piston, $0.785\ (14 \div 12)^2 = 1.06$ sq. ft., and the area of the 3-in. rod = 0.059 sq ft. Therefore to find the displacement of the piston on the return stroke from the crank end, we have

$(1.06 - 0.05) \times (15 \div 12) \times 10 = 12.6$ c.f.m.

The total volume, then, through which the piston will move each minute is 25.85 cu. ft. Steam pressure is assumed to remain at 100 lb. for the length of the stroke and the weight of steam per cu. ft. at this pressure is 0.26 lb. Therefore, the steam consumption of the pump is $25.85 \times 0.26 = 6.7$ lb. per min., 402 lb. per hr., or 4824 lb. in 12 hr., which, at an evaporation of 6 lb., would represent 406 lb. of coal every 12 hr. Your total saving, then, resulting from shutting down the pump and the steam lines mentioned, would be approximately 956 lb. of coal every 12 hr.

Editorial Comment

Shall Good Business Continue?

What makes good business? To all the answer is important, since good business results in steady work with good returns in wages, salaries, profits and dividends. Everybody wants those conditions secured and maintained. The analysis of conditions and causes by President Hoover's Unemployment Conference Committee on Recent Economic Changes has, therefore, universal interest.

Attention is called to the generally good business that has existed since 1922, to the stability of conditions and the industrial activity that has resulted. This is attributed to better understanding of economic forces, general coöperation, and greater self restraint in seeking selfish advantage. While advances have been "spotty" both as to industries and geographic location, in general markets have increased, the standard of living has risen and savings as well as enjoyment of comforts and luxuries have multiplied.

It is pointed out that no new factors have entered into business. Buying as needed, installment selling, coöperative marketing, chain stores have been used only to a greater extent than formerly, with added factors of greater use of power, which has increased 3¾ times faster than population, and greater productivity per man-hour due to increased use of power-driven machinery. This means that the unskilled worker has been transformed into a skilled operator of automatic machinery, with lowering of costs, elimination of drudgery and increase of wages.

Cost of living has decreased so that the purchasing power of wages has risen 2.1 per cent a year and it has been possible more and more to gratify the desire for goods and services, which comes with expanding human wants.

Fortunately, industrial leaders noted the effect of high wages in stimulating purchases and increasing savings which make capital available for further industrial expansion, as well as the principle of high wages and high productivity for lower cost of production. This has reduced the waste from strikes and lockouts and the increased demand for more than food, clothing and shelter has resulted in employing great numbers in production of what have heretofore been classed as luxuries as well as in service functions to provide travel, entertainment and education. Thus relief of unemployment has resulted by transfer of workers to these fields.

What of the future? The survey reveals that saturation of demand for conveniences is remote. Less than one-third of wired homes have washing machines or vacuum cleaners, only 5 per cent electrical refrigerators, 70 per cent of homes are yet without radio and similar conditions exist as to other commodities. There are great possibilities for articles already developed as well as ever increasing wants being created.

To maintain our economic advantage, the survey points out that the principle of equilibrium must be recognized and applied by economic use of natural resources, especially the land, by keeping adequate funds employed in business rather than diverted to excessive speculation, by avoiding selfish effort for artificial price advancement and by recognition of the common interest of management and labor in steady production.

With better knowledge of consuming habits, overproduction and resulting shutdowns can be avoided, funds and credits can be utilized rationally to energize industry and development can go steadily forward. But the organic balance of business and industry can be maintained only by intelligent, persistent effort, by mutual confidence and consideration and by the will to work harmoniously toward that end.

Approach to Perfection Is Expressed in Beauty

Every line of human endeavor has had its beginnings amid crude, practical surroundings with little thought about the aesthetic possibilities. Food, clothing and monetary returns have invariably been initial incentives for developing ideas into usable material form. It is only after the bare necessities have been met that refinements are given thought and worked out. Following perfection of design for safety and economy, invariably has come the human endeavor to beautify, to make surroundings more attractive, to cultivate the desires for higher education, deeper investigation and human understanding.

Compared with other industries, the power plant, as we know it today, is young. The original boiler and engine plant with its dirty coal and ash piles and smoking chimney without question belonged in the back yard of the factory it served. Today, however, the objectionable features of a power plant which are unavoidable are no greater than those accompanying the manufacture of almost any product. Its place in the scheme of things is, therefore, not among the alley cats but on a par with the important buildings of any industry. Many of the utility companies realize that the public judges the reliability of their institutions by what it can see of their possessions and have gone to the extent of bringing their buildings and grounds up to a standard of beauty in harmony with the standard of service they render.

Beautiful buildings and surroundings, we judge, are occupied by men with commendable ideals and intelligence. Machinery and other equipment would be expected to be in harmony with the other surroundings, that is, of high efficiency and in perfect condition. This may not be the existing combination. There are a few show plants among central stations and industrial plants where the equipment is not as efficient as might be expected but the really run-down plant is almost always found in a building of like character and it is only as perfection of operation is approached that the men in

charge turn their attention to beautifying their surroundings.

Engineers are approaching the limit of efficiency in the operation of their plants and we believe the time is at hand when the industry needs, for its own good, to bring its architecture and landscaping up to a point in harmony with its engineering attainments. In this issue, therefore, three articles are presented bearing on this subject which give the reactions of an engineer, an architect and a public utility official. Their opinions, we believe, are the reflections of leaders in the field and the growing interest insures better looking power plants throughout the country.

Determining Municipal Power Plant Costs

According to a recent news report, the Massachusetts legislature at its last session passed a bill providing that municipal power plants must include in their production costs the items of interest on invested capital and of reasonable allowances for depreciation. Naturally, this action has aroused a great deal of discussion in Massachusetts and has served to reopen the argument between supporters and opponents of the municipal power plant.

Now, although it is perfectly true that the primary purposes actuating the municipal plant and the privately-owned public utility are different, the fact remains that their product is the same, electric power. If we are to compare them, therefore, it is only common sense as well as sound economics to use the same factors of comparison for each plant.

Theoretically, the sole purpose of a municipality in operating its own power system is to make available a desired service to all members of the community alike. Note that we said theoretically. How the purpose may work out in practice is another story. Neither shall we consider here the question of whether or not the making of power is a legitimate function of government.

On the other hand, the actuating purpose behind the privately owned utility is the making of money, rendering, to be sure, a great service to humanity in the selling of household appliances and the making of electric power,—but primarily the making of money. It so happens that the product it sells in order to do this is electric power, the same product as that of the municipal plant.

For that reason, the municipal plant will always be judged by the average citizen and taxpayer on the basis of comparisons of the cost of power. It is all very well to say that the municipal plant is maintained as a gesture of civic pride or as a political measure or because of some feeling of antipathy to the utility companies and to protest that, even if it does cost the taxpayer more to run it than it would to buy power, it is still a project worth maintaining. That may be perfectly true in some cases, yet it is hard to make the average taxpayer see it. In most cases, all the arguments in favor of the municipal plant must be reduced to the one argument that it can supply the citizen with power cheaper than the utility can. Most taxpayers, especially in the smaller towns, are business-minded these days. Even if they do not operate businesses of their own, it is only human nature for them to like to participate in an enterprise that saves them money.

When they find, however, that in order to make the savings that are calculated, their plant accounting system fails to take into account the interest they must pay on money they have borrowed to build the plant and the money it takes to keep it in good operating condition and fails to provide for its renewal when worn out, it is a different story. But this money must come from somewhere. Some citizens begin to wonder whether it is not included in other forms of taxes, so that they are paying it anyway. The public utility includes all these items in its costs and still makes a profit. Sometimes, as we said before, the citizen begins to wonder.

There are, of course, many municipal plants in this country that can operate in such a way as to pay interest, depreciation charges and amortization and still maintain rates lower than those of the utility. Success in doing this, it seems, depends largely on the men who are running the enterprise, just as in the competitive industries and in the utility business itself, success depends on the men behind the guns. Besides, it should not be forgotten that a municipal plant does not have to pay profits to stockholders.

The important point in the entire discussion of municipal and utility power seems to be that the citizen should not fool himself. He ought to recognize that, in order to make a comparison between any two businesses, the same factors must be used in each case. Furthermore, if his municipal plant is built with borrowed money, he is paying interest on it in some form whether the item appears on the cost sheets or not. In addition, if he allows depreciation of the plant to occur, it will cost him more to make power with it. The question of replacing the plant at the end of its life is a difficult one for a growing community, yet the utility faces the same problem in supplying changing loads.

If the taxpayer, then, will resolutely refuse to deceive himself regarding the costs of his municipal plant, he will be much better off in the long run. If he cannot make power cheaper than the utility, including in his costs interest, depreciation and even amortization, he will find it difficult to justify his stand, in the view of engineers and business men, solely on the grounds of civic pride, politics or personal opinion. If he can include those items in his costs and still beat the public utility rates, he need not fear criticism.

Light's Golden Jubilee

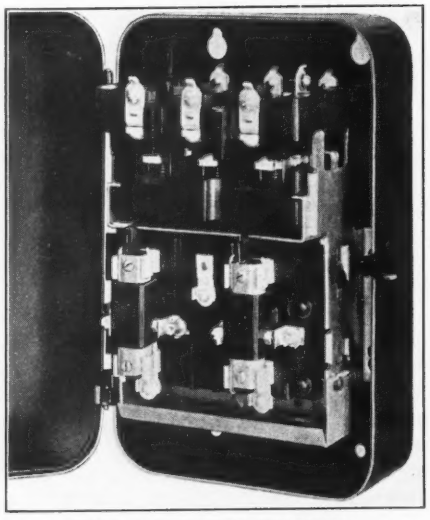
When electricity was put into commercial use, there came with it a new school of thought in the minds of men. It inaugurated an entirely new phase of industry and living conditions which we today are beginning to enjoy. Application of pure science to industry began about that time and the technically trained man has become the rule in the electric light and power field.

This year, which is the fiftieth since Thomas A. Edison produced the first incandescent lamps, is to be celebrated throughout the country by appropriate tributes to the ingenuity of a leader of men and to the outcome of his labors. The general committee sponsoring Light's Golden Jubilee is headed by President Hoover and the celebration will be opened as one feature of the fifty-second convention of the National Electric Light Association. All honor to the man who has turned night into day!

Power Plant Engineering Developments and News

Type A-30 Across-the-Line Motor Starter

DEVELOPMENT of a new across-the-line air motor starter known as type A-30 for use with squirrel cage induction motors up to 20 hp., 550 and 440 v.; 15 hp., 220 v., 7½ hp., 110 v., is announced by Condit Electrical Mfg. Corp., Boston, Mass.



TYPE A-30 MOTOR STARTER

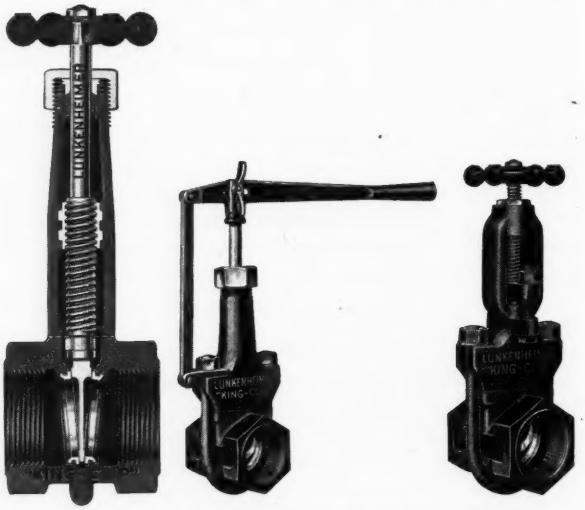
Hitherto, the company states, the arc with its accompanying effects of gas and contact burning has been assumed unavoidable in circuit interruption and efforts in the design of circuit-interrupting devices have been directed to extinguishing this arc as speedily as possible only after it has formed.

The type A-30 unit, however, is designed to prevent the arc from forming, thereby eliminating the formation of gas and permitting relatively no contact burning on normal operation. This motor starter, it is stated, when tested with a 20-hp., 440-v., squirrel cage induction motor, opened and closed the locked rotor current 437 times at 10-sec. intervals (when motor heating compelled the test to cease) without an arc at any interruption—only a spark and with scarcely perceptible contact deterioration. Fifty thousand operations at twice normal current on circuits of 55 per cent power factor at maximum rated voltage caused less deterioration, it is claimed, than a few such duty cycles on similar rated present devices.

Having no barriers or arc chutes, the type A-30 is unusually simple and compact. It is enclosed in a substantial, pressed steel case arranged for conduit knockouts. It is furnished electrically operated with thermal relays for time-lag overload protection and is arranged for undervoltage protection.

King-Clip Gate Valves

FOR USE on steam, oil, gas, air, water and gasoline lines, the King-Clip gate valve, shown herewith, has recently been put on the market. It is made in three designs: rising stem inside screw, outside screw and yoke, and quick operating. All types are procurable in iron body, bronze mounted and all-iron pattern, with screw or flanged end. The valve as a whole is designed to withstand rough usage. The body is of iron especially alloyed for valve service. Thread length is designed to accommodate both the American standard and A.P.I. line pipe. Flange end valves have flanges of the 125-lb. American standard for iron flanges and are plain faced. Face to face dimensions on flange end valves are standard trade practice.



KING-CLIP GATE VALVES ARE MADE IN THREE PATTERNS: (LEFT) RISING STEM INSIDE SCREW; (CENTER) SLIDING STEM, QUICK OPERATING; (RIGHT) RISING STEM OUTSIDE SCREW AND YOKE

To secure a simple but effective method of connection between the body and bonnet, a steel clip is provided, as shown. This is intended to facilitate the dismantling of the valve for cleaning or inspection and to lend strength and rigidity to the body. The stuffing box is designed to hold an ample supply of packing. Screwed stuffing-box nut is used on valves up to 3 in.

inclusive; sizes 1 in. to 3 in. inclusive have gland follower. On 3½-in. and 4-in. valves, a bolted iron gland is used. Bronze bushings in the bonnet are designed to provide a non-corrosive contact with the bronze stem to protect the stem thread and to insure easy operation. The stem has rugged, wear-resisting thread of generous length. A shoulder above the stem thread is intended to form a tight contact with the seat under the stuffing box to permit repacking the valve under pressure when it is wide open.

The disc is sharply tapered to make the valve adaptable for handling heavily impregnated fluids. The disc-stem connection in the iron-body, bronze-mounted valve is in the form of a horseshoe band to impart extra strength to this part. Seat rings are permanently rolled in to prevent them from loosening. Iron-body, bronze-mounted valves, inside screw patterns, have iron body and bonnet; bronze bonnet bushing, disc, seat rings, stem, stuffing-box nut and gland; steel clip. The quick-operating sliding stem patterns are of similar material construction to the inside screw pattern, except that the handwheel is replaced by an iron lever attachment to permit extremely rapid valve operation. Outside screw and yoke valves have iron body, yoke and gland; bronze yoke bushing, disc, seat rings and stem; steel clip. In the all-iron pattern, all parts except the bronze yoke bushing in outside screw and yoke valves, are made of ferrous metals. All iron valves are for use in handling solutions which attack bronze but not iron. Sizes up to 2 in. inclusive have permanently rolled in steel seat rings. Larger sizes have integral seats.

Pressure ratings of King-Clip gate valves are as follows: screw ends ¼ to 2 in. inclusive, 150 lb. working steam pressure, 225 lb. gas or liquid pressure; screw ends 2½ to 4 in. inclusive and flange ends 1½ to 4 in. inclusive, 125 lb. working steam pressure, 175 lb. gas or liquid pressure. King-Clip valves are a recent product of the Lunkenheimer Co., Cincinnati, Ohio.

Tests of Safety Valves on Superheaters

SUPERHEATERS are usually protected by setting their safety valves to blow before those on the boiler drum, a procedure which, under usual conditions, imposes most of the relief work on the superheater safety valves. Accurate setting and functioning of these valves are important, therefore, especially in connection with the high superheat carried in many modern high-pressure stations and industrial plants.

Satisfactory operation of any safety valve demands an adequate blowdown, provision for which must always be made in determining the pop setting. After the correct popping pressure is established, it is essential that the valves pop consistently at this pressure. Any decrease in popping pressure results in a corresponding drop in closing pressure; this pressure loss wastes steam, cuts down the line pressure and seriously impairs turbine efficiency and capacity.

During the intervals between pops, a safety valve forms a dead end and, even when mounted on a superheater outlet, the valve body and other parts cool down considerably below the temperature which they attain while the valve is popping. The closer the spring is to the valve body, the more it is affected by these temperature changes.

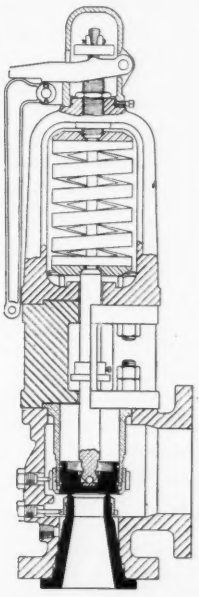


FIG. 1. CROSS-SECTION OF MODEL HNA NOZZLE-TYPE SAFETY VALVE, SHOWING COOLING SPOOL

Safety valve construction with spring mounted entirely above the valve body has proved desirable for high-pressure, high-temperature relief, it is claimed, but this position alone has not been found wholly adequate to keep the spring temperature low and uniform enough to avoid changes of popping and closing pressures with highly superheated steam.

The Model HNA Crosby nozzle-type safety valve, recently developed for high-temperature superheated steam, as shown in Fig. 1, is designed to provide for practically normal, constant, low, spring temperature through entire separation of the spring from the valve body. This is accomplished, it is stated, by inserting a cooling spool between the body and spring yoke or valve bonnet. The spool is shaped to provide as little metal for conduction of heat and as much surface for air-cooling as is consistent with adequate strength.

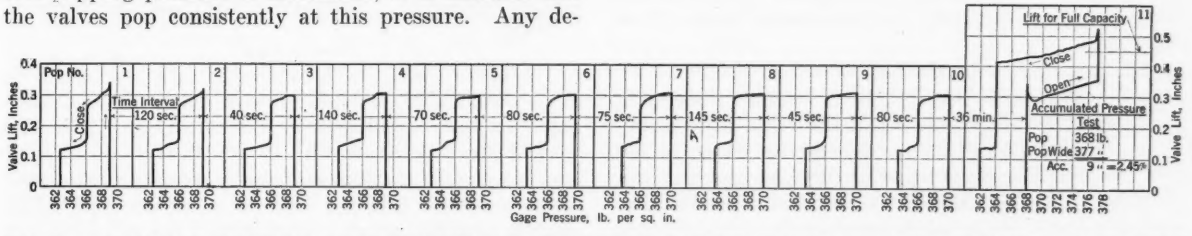


FIG. 2. DIAGRAMS SHOWING PERFORMANCE OF MODEL HNA SAFETY VALVE ON SUPERHEATER AT KEARNY STATION

Performance of valves fitted with the cooling spool is shown by the accompanying diagrams, Fig. 2, taken from a test at Kearny Station of Public Service Electric & Gas Co. of Newark, N. J. The test valve, mounted on the superheater outlet of a boiler in regular service, was set to pop at 369 lb. per sq. in., with steam heated to an average of 690 deg. F.

These diagrams were made by a lift-indicating device, to show the relation of valve lift to pressure. Ten consecutive pops were produced as closely after each other as the pressure could be manipulated. Neither the popping nor closing pressures varied more than 1 lb., the blowdown throughout being slightly under 2 per cent. Following these 10 pops, the spool was extremely hot but a hand could be held comfortably on all parts of the valve bonnet. The bottom spring washer and the dead end of the spring were fairly warm but all the working coils were completely cool.

After a wait of about half an hour, a test in which the pressure was built above the popping pressure was run to develop the maximum lift and discharge capacity according to the A.S.M.E. rating. The A.S.M.E. Boiler Code states that the rated discharge capacity of a safety valve shall be determined at a pressure of 3 per cent in excess of that at which the valve is set to blow. Here also the pop and blowdown pressures did not vary more than 1 lb. from those of the earlier test. (See table.)

TABLE OF RESULTS OF TESTS AT KEARNY STATION OF MODEL HNA SUPERHEATER SAFETY VALVE

Pop. No.	Time Hr. Min. Sec.	Popping Pressure	Closing Pressure	Blow down per cent
1.....	10—15—30	369	362½	1.75
2.....	10—17—30	369	362½	1.75
3.....	10—18—10	369	362½	1.75
4.....	10—20—30	369	362¾	1.69
5.....	10—21—40	369	362¾	1.69
6.....	10—23—00	369½	363¼	1.69
7.....	10—24—15	370	363½	1.75
8.....	10—26—40	370	363½	1.80
9.....	10—27—25	370	363¼	1.80
10.....	10—28—45	370	363¼	1.80
After a wait of one-half hour, the following were recorded:				
*.....	10—56—20	369	363	1.62
11.....	11—34—45	368	362	1.62

*Not shown in diagram. Includes accumulation of pressure above popping pressure of the valve.

As the diagrams show, the pop is clean and sharp to a lift of about 5/16 in. Closing takes place in two steps, the final drop being from a lift of about ⅛ in. If pressure increases above the pop setting, the valve disc jumps to a lift greater than that necessary to develop the full-bore nozzle capacity, which is well within the 3 per cent accumulation limit set by the A.S.M.E. Code. With reduction of pressure, closing takes place in two steps, the final drop being as before from a lift of about ⅛ in. These tests also show clearly that the valve disc closes on a steam cushion which eliminates hammer blow effect.

Valves with the original construction described are available and have been supplied for operating pressures up to 1400 lb. Existing Model HN Crosby safety valves can be simply and completely converted to this new Model HNA by interposing the cooling spool, substituting a longer spring spindle for the old and adding a small collar. These valves are made by Crosby Steam Gage & Valve Co., Boston, Mass.

N. E. L. A. Meets June 3-7 at Atlantic City

AS A CLIMAX to several other related events, the 52nd convention of the National Electric Light Association will be held at Atlantic City, N. J., from Monday, June 3, through Friday, June 7. The exhibition held in conjunction with the convention was scheduled to open on Friday, May 31. Dedication ceremonies of the Atlantic City Auditorium were scheduled for the same day. Initial celebrations of Light's Golden Jubilee, as well as festivities marking the diamond jubilee of Atlantic City, will take place during the convention week.

Programs of the business sessions of the convention will include addresses and discussions on regulation, industrial development, research, rate making, commercial opportunities, accounting practices, public relations, engineering developments and the Federal Trade Commission's investigation of the electrical industry.

General sessions will be held each morning and meetings of accounting, commercial, engineering and public relations sections are scheduled for the afternoons. The general session for Thursday will be in the nature of a tribute to Thomas A. Edison. He is expected to appear both in person and in a talking movie. Henry Ford will also be on the speakers' platform to do honor to Mr. Edison. At this session, the principal speakers will be Charles L. Edgar, Thomas H. McCarter, John W. Lieb and Berton Braley.

At the Public Policy session on Thursday evening, the Charles A. Coffin award will be presented, there will be addresses by prominent speakers and entertainment by Frieda Hempel, soprano, and Albert Spalding, violinist. The latter part of this session will be broadcast by the WEAF Red Network.

Throughout the convention, music will be provided by B. A. Rolfe's orchestra and there will be dancing every evening. A reception to President and Mrs. Arkwright will be held on Monday evening, June 3. Entertainment for the ladies attending the convention will include a golf tournament at Seaview Golf Club on Tuesday, June 4, and a card party on Wednesday afternoon.

Charles S. Curtis, vice-president of the United States, together with the British and Spanish ambassadors, several senators and congressmen and officials of the N.E.L.A. will take part in the formal dedication of the Atlantic City Auditorium on May 31. Electrical displays by the U. S. S. Wyoming and the dirigible Los Angeles have been arranged, as well as airplane exhibitions.

Electrical displays will be specially arranged for the occasion so that the entire atmosphere of the city and the convention will express the spirit of the electrical industry.

To AVOID boring holes through a line pole which is to be dead-ended, a dead-end sling of preformed wire rope has been developed by the American Cable Co. Special steel cylinders with eyes attached are slipped over the ends of the rope and, by hydraulic pressure, are securely locked into the interstices of the rope. The sling is wrapped around the pole and the end joined to a shackle and copper pin for connection to the guy.

Delray 10,000-Kw. Turbine to Operate at 1000 Deg.

JUST AS THIS ISSUE was going to press, an article was received from J. W. Parker, chief engineer of The Detroit Edison Co., describing the features of a turbine generator, recently ordered by that company for Delray Power House No. 3, to operate with an admission steam temperature of 1000 deg. F.

According to this article, The Detroit Edison Co. has placed with the British Thomson-Houston Co., Ltd., Rugby, England, a contract for a 10,000-kw., two-cylinder, single-shaft turbine generator to operate with an admission steam temperature of 1000 deg. F. Inlet pressure will be 365 lb. gage, conforming to the boiler pressure of Delray Power House No. 3, while the exhaust pressure of 1 in. mercury absolute is that usually afforded in plants to which excellent circulating water is available.

It is planned to install the high-temperature turbine and its separately-fired superheaters in a corner of the boiler room in the new Delray plant, where space has been left available by omission of one boiler from the first battery in the plant. Steam taken from the main superheated steam line at 400 lb. pressure and 725 deg. F. will be passed through an oil-fired superheater designed to deliver a maximum of approximately 83,000 lb. of steam an hour; the steam will then pass directly to the turbine.

Mr. Parker's complete statement will appear in the next issue of Power Plant Engineering.

News Notes

NATIONAL DISTRICT HEATING ASSOCIATION will hold its 20th annual convention at the Hotel Statler, Detroit, Mich., from June 11 to 14 inclusive. Reports of the various committees will contain discussion of recent developments in district heating, plant operation, distribution, rates, commercial relations and other pertinent matters. An interesting entertainment program, which includes the annual golf tournament, has been arranged. Reservations should be made directly with the Hotel Statler and further details can be obtained from D. L. Gaskill, secretary of the N. D. H. A., Greenville, Ohio.

STRONG, CARLISLE & HAMMOND CO., Cleveland, Ohio, has granted exclusive sales rights for its products to the following new agents: Moore-Handley Hardware Co., Birmingham, Ala.; Bright & Co., Reading, Pa.; The Mason Equipment Co., Toledo, O.; Industrial Supplies, Inc., Memphis, Tenn.; Nashville Machine & Supply Co., Nashville, Tenn.

CHICAGO PUMP CO., 2336 Wolfram St., Chicago, Ill., announces the addition of W. T. Morgan to its organization. Mr. Morgan was formerly with Goulds Pumps, Inc., and will be assigned to the New York office as manager of engineering service.

JOSEPH DIXON CRUCIBLE CO., Jersey City, N. J., announces several important changes in its line of paint. Dixon's Industrial Paints, known as Dixon's Silica-Graphite Paints, have been increased in range of colors from 8 to 14 colors to include a straight aluminum paint and a standard red oxide paint. Dixon's Bright Aluminum Paint contains a durable spar varnish as its vehicle to give great resistance to the elements and to insure the life and brilliancy of the aluminum pigment. Dixon's Utility Paints have been added as standards, three of which are graphite-pigmented, the fourth, oxide of iron. The paints are made to have all the qualities of a good protective coating at a low cost and are designed for use on general run of work. They are made in four standard colors. Dixon's Maintenance Floor Paints have been developed for the protection of wood, composition, linoleum, cement and concrete floors, designed to be immune to the action of alkali and to prevent dusting of concrete floors. They are intended to be used inside or out and to withstand the rigors of weather and climatic changes. They are made in eight standard colors.

BOILER ENGINEERING CO., Newark, N. J., announces that H. A. Woodworth Engineering Co., Suite 313, Central National Bank Bldg., St. Louis, Mo., is its representative for Missouri and southern Illinois. It has also appointed Steam Specialty Sales Co., 5 South Church St., Charlotte, N. C., H. P. Ackerman, manager, as its representative for North and South Carolina.

BAIN & ROBB, 2118 Lyndale Avenue, South, Minneapolis, Minn., engineers, have been engaged by the Shaft-Pierce Co., Faribault, and a group of other mercantile concerns, operating a central steam power plant for heating service, to prepare plans for an addition to present unit, including installation of additional equipment. Project is reported to cost close to $50,000.

CENTRAL ILLINOIS PUBLIC SERVICE CO. has been authorized by the Illinois commerce commission to purchase the Smithfield Light and Power Co. and to continue public utilities service in that section of Fulton County, heretofore served by the Smithfield company.

NORTHERN STATES POWER CO., Minneapolis, Minn., is reported considering a new steam-operated electric generating plant at Fargo and will carry out surveys and preliminary work at an early date. A site has been selected at Second St., near the Red River. Project is expected to cost more than $750,000. The Byllesby Engineering & Management Corp., 231 South La Salle St., Chicago, Ill., is engineer.

ROLLER-SMITH CO., 233 Broadway, New York, announces the appointment of J. C. McDougall, Alaska Bldg., Seattle, Wash., as its district sales agent for the states of Washington, Oregon and Alaska. The company also announces the appointment of Jackson Brown, Jr., 701 Kittridge Bldg., Denver, Colo., as its district sales agent for Colorado, Utah, Wyoming and New Mexico.

JOHNS-MANVILLE CORP., 292 Madison Ave., New York City, announces the acquisition of the United States and Canadian rights to manufacture and sell transite pipe, a seamless pipe made of asbestos and cement, under the patents of the Eternit Pietra Artificiale, Societe Anonima, of Genoa, Italy. While entirely new to America, it is stated, this pipe has been in use in Europe for a number of years under various conditions of soil and for a great variety of purposes. It will be manufactured by Johns-Manville Corp. in five general classes: one class of light weight pipe for flue piping and exhaust stacks and four pressure classes to carry liquids at working pressures of from 40 to 225 lb. per sq. in. The flue pipe, it is stated, is not affected by

the ordinary stack temperatures and is especially adaptable to the venting of house heating boilers and automatic water heaters and for chemical service. The pressure pipe is designed for delivery of hot or cold water, brine and various process liquids and solutions under pressure. It is reported that a number of foreign cities have used it for gas distribution. The process for manufacturing this pipe is designed to produce a dense, close grained material which, it is claimed, can be readily cut, tapped or threaded with the same tools and in the same manner as iron pipe. Its weight is stated to be from 50 to 65 per cent less than cast iron or steel pipe. Especially designed machinery for its manufacture is now being built in Italy and two complete units with a capacity of 2,000,000 ft. of pipe per year will be soon be installed at the Waukegan, Ill., plant of the Johns-Manville Corp. The pipe will be made in sizes from 2 in. to 40 in.

CONTRACTS have been placed with the Allis-Chalmers Manufacturing Co., Milwaukee, Wis., covering equipment for the extension of the Waukegan Generating Station of the Public Service Co. of Northern Illinois, Sargent & Lundy, Inc., Engineers, including a 65,000-kw. tandem steam turbine-generator unit with condenser, circulating water pumps and condensate pumps. Unit No. 4 will be rated 65,000 kw., tandem-compound with one generator and will be similar to the 50,000-kw. unit No. 3 except it will be arranged for boiler reheat. The operating conditions are 600 lb. steam pressure, 725 deg. F. total steam temperature and 29 in. vacuum referred. The electrical end is 60-cycle, 3-phase, 12,000 v., and includes a 250-v. direct connected exciter. Condenser equipment consists of a 63,000-sq. ft., oval section, two-pass surface condenser; two 42-in. by 36-in. vertical circulating water pumps, having a capacity of 37,500 g.p.m. each driven by 250-hp. two-speed vertical squirrel cage motors; two 10-in. by 5-in. two-stage centrifugal condensate removal pump units, capacity 1200 g.p.m. each, driven by 150-hp. motors; two Croll-Reynolds twin evactor three-stage steam jet air pumps.

FORMATION OF International Hydroelectric System as a Massachusetts voluntary association, has been recently announced. The new company, of which A. R. Graustein is president, will own directly over 82 per cent of the outstanding common stock of New England Power Association and the entire common and second preferred stocks of Canada Hydroelectric Corp., Ltd. Through these subsidiaries, the new company will control one of the largest groups of hydroelectric properties in the world, it is stated.

CHASE CO., 43 Exchange Place, New York City, acting as agents for the Industrial Institute, Inc., 26 Court St., Brooklyn, N. Y., has completed negotiations with the City of Toms River, N. J., to transfer 50 acres of land for the establishing of a training school for the practical education of men in Diesel engineering for land and marine and aviation services and for other courses in engineering. The project is sponsored by Julius Rosbloom and his associates include a number of engineers intimately concerned with Diesel engine work.

NEW ENGLAND POWER ASSOCIATION, Boston, Mass., has concluded negotiations for the purchase of the Fall River Electric Light Co., Fall River, Mass., and will consolidate with its organization. It understood that purchasing company will carry out an expansion and betterment program in the Fall River district, including transmission line construction to connect with main system. The Eastern Utilities Association, operating the Blackstone Valley Gas & Electric Co., Pawtucket, R. I., is interested in the acquisition of the Fall River property and will furnish certain power service to that vicinity in the future in connection with its ownership of the Montaup Electric Co., Somerset, Mass. The New England Power Association also operates properties at Worcester, Lowell, Lawrence, Webster and Southbridge, Mass., and owns a controlling interest in the Narragansett Electric Light Co., Providence, R. I.

MICHIGAN VALVE & FOUNDRY CO., P. O. Box 822, Detroit, Mich., has inaugurated a new service whereby technical advice is made available to those in charge of projects involving water supply and distribution, drainage and sewage works, particularly where piping is an important factor. Administration of this service has been placed in charge of Eldon S. Clark, who has been associated with many important projects of this type for such companies as Barrows & Breed, Stone & Webster, Inc., and Metcalf & Eddy.

GENERAL ELECTRIC CO. sales billed for the first 3 mo. of 1929, announced by President Gerard Swope, amounted to $83,385,015.49, compared with $71,640,-790.40 for the corresponding period last year, an increase of 16 per cent. Profit available for dividends on common stock for the first quarter of 1929 was $13,862,-298.06, compared with $11,261,842.71 for the corresponding 3 mo. last year. The profit available for common stock for the quarter is equivalent to $1.92 per share in 1929 and $1.56 per share in 1928. Orders received during the first quarter of 1929 amounted to $101,365,208, compared with $79,925,840 for the corresponding quarter last year, an increase of 27 per cent.

WILLIAM EUGENE KEILEY, writer and editor, known especially during the last few years in the public utility field, died early on April 23 at the Hotel Webster, Chicago, Ill., following a three-day attack of angina pectoris. From 1891 to 1908, Mr. Keiley was associate and later managing editor of the Western Electrician in Chicago and from 1909 to 1914 was western editor of the Electrical World. Since that time, he has been with the Commonwealth Edison Co. and other Chicago utilities.

DES MOINES VALLEY POWER CO. has been issued permit to operate in Iowa and Frank Maher, president, announced that preliminary plans for the hydroelectric plant at Kalo have been completed.

EDWARD VALVE & MANUFACTURING CO., East Chicago, Ind., is now represented in Baltimore, Md., by D. C. Elphinstone, Inc., 120 S. Calvert St.

MARQUETTE CEMENT MFG. CO., Marquette Building, Chicago, Ill., plans installation of power equipment in connection with proposed extensions and improvements in mill at Cape Girardeau, Mo., entire project reported to cost more than $350,000.

STEAM POWER PLANT is projected in connection with a proposed cotton mill to be constructed at New Braun-

fels, by James McDowell, City National Bank Building, San Antonio, Texas, and associates. A company, it is understood, is being organized to carry out the enterprise, which is reported to cost more than $500,000.

United States Civil Service Commission announces an open competitive examination for mechanical engineer, applications for which must be on file with the commission at Washington, D. C., not later than June 19, to fill vacancies in the position of Chief of Mechanical Service, U. S. Penitentiary Service, Atlanta, Ga., and Leavenworth, Kansas, and vacancies occurring in positions requiring similar qualifications. Entrance salary is $3800 a year. Higher-salaried positions are filled through promotion. Competitors will not be required to report for examination at any place but will be rated on their education, experience and fitness. Full information may be obtained from the United States Civil Service Commission, Washington, D. C., or, at the post office or customhouse in any city.

MacLaren Fir Co., Buckingham, Que., has approved plans for the immediate construction of a hydroelectric power plant on the Lievre River, near High Falls, for lumber mill, logging, and other power service, reported to cost close to $10,000,000 with transmission lines.

City Council has approved a franchise for the Municipal Utilities Co., Liberty Building, Des Moines, Iowa, covering the construction and operation of a local electric light and power plant and it is understood that project will proceed at an early date, reported to cost in excess of $60,000.

Prairie du Chien Woolen Mill Co., Prairie du Chien, Wis., has asked bids on general contract for extensions and improvements in boiler house and power plant, reported to cost about $75,000, with equipment. Charles A. Cahill & Sons, 214 Mason St., Milwaukee, Wis., are engineers.

Books and Catalogs

Anthracite Sizes for Domestic Use, by R. H. Fernald; published by the Mechanical Engineering Department, Towne Scientific School, University of Pennsylvania, Philadelphia, Pa.; 74 pages.

Results of an extensive investigation to determine the relative economic values of various types of fuel for house heating and cooking arrangement. The results are of interest to the power plant operator as showing the advantages of sized coal. From the standpoint of excellence of general performance, uniformity of combustion, ease of fire control, freedom from clinkering, ease of fire cleaning and general high efficiency, the anthracite mixture, 80 per cent chestnut and 20 per cent pea, took first rank of the fuels tested.

Elementary Differential Equations, by Thornton C. Fry; published by D. Van Nostrand Co., Inc., 8 Warren St., New York City; 9 chapters, 241 pages; price, $2.50.

Evolved through several out-of-hour courses of the Bell Telephone Laboratories, this book is well suited for students of engineering and those who desire to review the subject. Technical illustrations and applications are numerous and in order to avoid the possibility of the student passing over without the deeper understanding of principles, this practical material has been collected into separate chapters.

Serial Report on Coal and Ash Handling for March, 1929, has just been issued by the Prime Movers Committee, Engineering National Section of the National Electric Light Association, 420 Lexington Ave., New York City. During the past year, the report states, probably the most notable development in the handling of coal and ash has been the introduction of the molten slag method of removing pulverized fuel ash from the furnace. Two member companies report the successful adoption of such a system of ash removal. For stoker-fired boilers, one member company gives complete maintenance cost for various types of ash hoppers and gates. Two statements are presented showing new coal handling equipment and two member companies give data on the commercial disposal of ash. A complete test is reported on a new coal distributor spout and a statement made regarding its operation. Use of the drag scraper system for storing coal is steadily growing, according to this report. Statements from five manufacturers are given, covering, among other items, a motor-operated ash gate and a new vestibule-type ash hopper. Problems to be studied by the committee are as follows: further developments in handling pulverized fuel ash as molten slag; the removal of ash dust from flue gas by electrical precipitators and other methods; the commercial disposal of ash; and new designs of coal and ash handling equipment. A brief bibliography is included.

Illinois Coal, by A. Bement. Published by the State of Illinois, Department of Registration and Education; 112 pages.

Published as bulletin No. 56 by the division of the State Geological Survey, this is a non-technical account of the occurrence, production and preparation of Illinois coal and has been prepared primarily for the public rather than for the technical miner. It is written in an interesting manner, well illustrated by photographs, maps and drawings, and should prove of interest to all engineers interested in the utilization of Illinois coal.

Heat Transfer in Ammonia Condensers. By Alonzo P. Crafts, Horace J. MacIntyre, Richard E. Gould; published as bulletin No. 186 by the Engineering Experiment Station, University of Illinois, Urbana, Ill.; 26 pages; price, 20 cents.

This bulletin is a continuation of Bulletin No. 177 which dealt with the performance of three different types of ammonia condensers. The present bulletin comprises the study of effect of certain changes in the condenser surface of the vertical shell and tube condenser and an extension of the investigation of the heat transfer in the double pipe superheat remover used in connection with previous tests in the shell and tube condenser.

American Society of Heating & Ventilating Engineers Guide, 1929, Seventh Edition; 844 pages, 6 by 9 in., cloth; published by American Society of Heating & Ventilating Engineers, 29 W. 39th St., New York City; price, $5.00.

This is the seventh consecutive annual edition of the Guide. During the year, improvements have been rapid in heating and ventilating so that this edition contains many new chapters and many new catalog data from manufacturers. A variety of subjects is covered in the 34 chapters, particular attention being called to the

amplified information on heat losses from buildings, radiators and heaters, steam heating systems and piping, heating boilers, ventilation standards, methods of drying, natural ventilation and so on. New chapters have been added on chimneys, fan furnace heating, central heating systems, heat exchangers, laundry, kitchen and hospital equipment and fans for heating and ventilating.

Much of the information contained in previous issues of the Guide has been rearranged and revised and, of course, as time goes on, some of this information must be modified in the light of the latest discoveries. This is a point that engages the careful attention of the Guide Publication Committee, so that the user of the Guide may feel confident that on any subject he is reading the latest and most authoritative information that is available.

Typical examples, tabulations of data, and use of graphical methods make the Guide especially convenient for the operating engineer as well as for the designer. In short, we reiterate our previous recommendation as to the Guide; namely, that it is by far the most authoritative and usable treatment of the subject of heating and ventilating engineering that can be obtained at the present time.

SUPER SERVICE is the title of a 56-page illustrated bulletin issued by Foltz Furnace Co., Chicago, Ill. This bulletin is designed to aid the engineer in the solution of combustion problems and shows how this solution is attained by the use of the Foltz combustion system. Discussion is first given of the fundamentals of combustion and the Foltz combustion system is then described. The chief feature of the system is to separate the furnace air supply at its common source into two relative portions. One portion of this air at climatic temperature passes up through the grate and fuel body and the other portion is bypassed around the grate through heated regions and discharged in a preheated state over and above the fuel body to mix with the gases there. This second portion of the furnace air supply is caused to flow through air conduits encased in the walls of the furnace. These are designed to carry the proper quantity of air to support the complete combustion of all the gases and the quantities of air flow both through these conduits and through the grates and fuel body are properly proportioned to the thickness of the fuel body, rate of combustion and temperature of the furnace. The bulletin presents many results of tests on furnaces using this system of combustion and shows many photographs and drawings of actual installations that have been made.

COMPLETE BIBLIOGRAPHIES on various phases of the subject and a brief synopsis of present knowledge of the radiation of heat are included in the minutes of the Conference on Heat Transfer by Radiation by the Committee on Heat Transmission of the National Research Council, 40 West 40th St., New York City.

SERIAL REPORT on Specifications of the Prime Movers Committee, Engineering National Section of the National Electric Light Association, has just been issued for April, 1929. The purpose of the work of the Specifications Subcommittee is to formulate general specifications for the major items of power plant equipment in order to assist the specification writer in producing specifications which will clearly describe the equipment wanted and the performance expected of it under given conditions. It is recognized that inflexible standards cannot be set up to apply in all cases. The object of this report, therefore, is to furnish suitable forms to aid the specification writer in assuring that his specification will completely cover the material with a minimum of effort.

Previous reports covered general outline and standard forms for boilers, surface condensers, stokers, and many boiler accessories, as well as turbine generators, condensers and turbine generator accessories. The present report covers a general outline and standard forms for air preheaters, closed heaters and deaerating equipment. In addition to these, the subcommittee has, upon request, included in the present report, material on several related subjects of special interest to the specification writer or purchaser. This additional matter includes a form for analysis of proposals, an index of generally accepted standards and lists of reports of investigations. Copies of the reports may be obtained from National Electric Light Association, 420 Lexington Ave., New York City.

FOR THOSE wishing machine parts and commercial forms of nickel alloy steel, the International Nickel Co., Inc., 67 Wall St., New York City, has issued a convenient buyer's guide giving a list of such products and firms from which they may be obtained. Some of the headings, of interest to power plant managers are, roller bearings, bolts and nuts, connecting rods, crankshafts, forgings, gears, boiler plates, rivets shafting, staybolts, boiler tubes, turbine blading and valves.

TYPE K UNDERFEED STOKER for boilers up to 200-hp. is described and illustrated in Catalog K-2 issued by the Combustion Engineering Corp., 200 Madison Ave., New York City, and the details of construction are shown by photographs and drawings, also the application of the stoker to various types of boilers. The results of an evaporative test are also given in the catalog.

HUBER STOKERS, type AH, are completely described and illustrated in a recent bulletin, No. 903, by Flynn and Emrich Co., Baltimore, Md.

NICHOLSON FLEXIBLE COUPLING, which is an all metal, lubricated coupling, with case-hardened wearing parts, is completely described and illustrated in bulletin No. 329, recently published by W. H. Nicholson & Co., 12 Oregon St., Wilkes-Barre, Pa.

THREADLESS CONDULETS, Couplings and Connectors are described in Bulletin No. 2126 by Crouse-Hinds Co., Syracuse, N. Y.

TRAHERN ROTARY PUMPS of hand and power types for all purposes are described in catalog 54 by Geo. D. Roper Corp., Rockford, Ill.

INSTRUCTIONS FOR MIXING and Application of Enco Baffle Material are contained in a four-page folder known as bulletin EB-428, sent out by The Engineer Co., 17 Battery Place, New York City.

BOOK, No. 1167, a 38-page catalog showing detailed specifications of the 15,000 sprocket wheels it now carries in stock, has just been issued by Link-Belt Co., 910 S. Michigan Ave., Chicago, Ill. This book will be sent on request to anyone interested.